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The Journal of
Bone and Joint Surgery

THE DEVELOPMENT OF SARCOMA IN BONE SUBJECTED TO ROENTGEN OR RADIUM IRRADIATION *

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From the Department of Surgery, University of Chicago

Roentgen or radium irradiation sufficient to cause epithelial changes has been followed not infrequently by the development of carcinoma. Although less common than carcinoma, sarcoma in a superficial ulceration of an irradiated field is a well-known complication. Occasionally sarcoma has developed in subjacent soft parts after exposure to x-rays or radium. Since bone is the most common primary site of sarcoma, it is reasonable to expect that, when subjected to irradiation, it too may undergo late malignant change. The purpose of this paper is to present three patients in whom irradiation appears to have been responsible for the development of bone sarcoma. In each of these cases the tumor arose in normal bone which had been in the field of irradiation directed toward an independent lesion.

EXPERIMENTAL SARCOMA OF BONE PRODUCED BY X-RAY OR RADIUM

Most experimental work on the production of tumors by irradiation has been concerned with carcinoma and with superficial sarcomata. Tumors have been produced inadvertently in bones close to areas of irradiated tissue. Marie, Clunet, and Raulot-Lapointe, in 1910, observed such a tumor while they were working on the relationship of x-ray burns and carcinoma. Theirs was the first report of experimental sarcoma of bone produced by irradiation. Lacassagne and Vinzent, in 1929, treated with 1000 roentgen units a bacterial abscess adjacent to the femur of a rabbit, and noted an osteogenic sarcoma six and a half months later. Lacassagne also produced a fibrosarcoma of the tibia thirty-six months after 1980 roentgen units had been delivered over an abscess near the bone. He deduced that chronic infection facilitates the production of sarcoma by irradiation.

In 1931, Schürch and Uehlinger implanted a 1-microgram radium needle subperiosteally in the jaw of a rabbit and left it in place for twenty days. One and a half years later a spindle-cell sarcoma, with areas of cartilaginous and osteoid tissue, was found. Sabin, Doan, and Forkner, in 1932, studied the effect of intravenous injections of 5.1

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micrograms of radium chloride and also of 7.7 micrograms of mesothorium upon the bone marrow of rabbits. Osteogenic sarcoma was found subsequently in two of seven animals which survived eleven to nineteen months.

Schürch and Uehlinger, in 1935, placed vaseline impregnated with 2 to 5 micrograms of radium or mesothorium in the femora of twenty-two rabbits. Eighteen to twenty-one months later five animals had sarcoma at the site of the implant. Three of the tumors were osteoblastic and two were polymorphous or spindle-cell sarcomata.

In 1936, Jentzer produced sarcoma in the skull of a rabbit by the application of radium. The same year Ross implanted platinum tubes containing 0.1 milligram radium element in the thoracic wall of young rabbits; and an osteogenic tumor of a rib resulted in one animal.

Hellner, in 1937, in conjunction with his report of one clinical case of irradiation sarcoma, also described a polymorphous sarcoma, produced by repeated exposures of the lower end of the femur of a rabbit to radium. In the same year, Ludin directed to the tibia of a rabbit 8000 roentgen units over a period of six and a half months, and later found a chondrosarcoma.

In 1937, Daels and Biltris introduced a mixture of radium, paraffin, diatomaceous earth, and arsenious acid into the skulls of guinea pigs and two bone sarcomata resulted. Schürch and Uehlinger's third paper reported sarcomata in 50 per cent. of animals which survived exposure to radio-active material for a long period. The same authors, in 1938, described osteogenic sarcoma in fourteen of twenty-one rabbits in which 0.005 milligram of mesothorium had been implanted twenty-one to twenty-nine months before. Daels and Biltris, in 1938, implanted collodion strips impregnated with radium sulfate into the pectoral muscles of fowls. Osteogenic tumors were found in two of the birds four to five years afterward.

Dunlap, Aub, Evans, and Harris, in 1944, reported osteogenic sarcomata which appeared in the vertebrae or pelvic bones in nine of thirteen rats fed 100 micrograms of

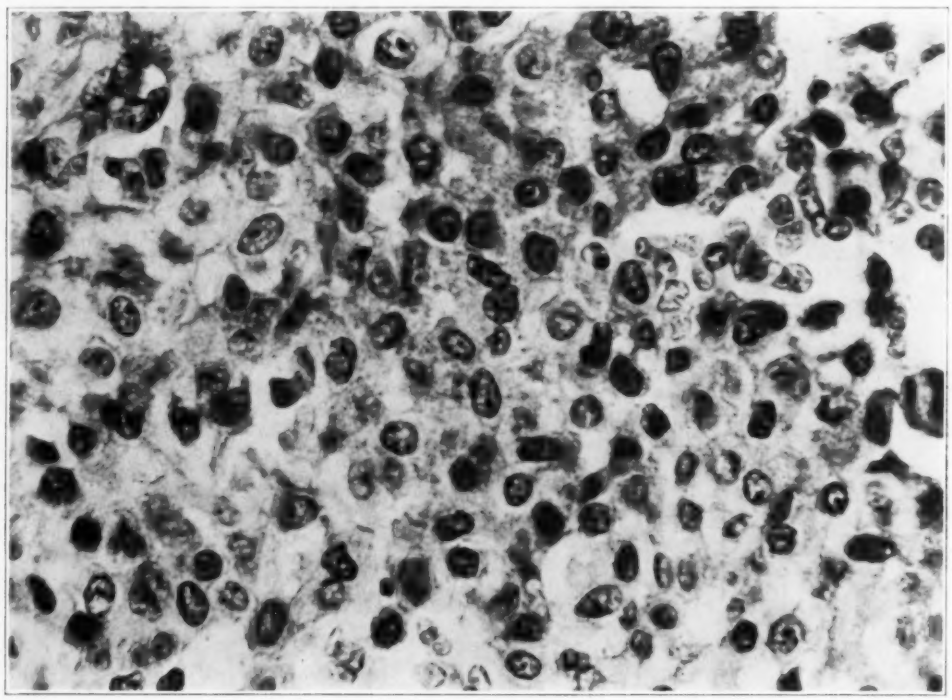

FIG. 1-A

Case 1. Photomicrograph (×300) of epiphyseal chondroblastoma of tibia.

FIG. 1-B

Roentgenograms four years after last roentgen exposure show: irregular sclerosis at site of original epiphyseal tumor of tibia; partial destruction and replacement of the proximal end of fibula by mass of variable density.

radium. The average interval from the time of radium ingestion to discovery of the tumors was 365 days. Three of the tumors were successfully transplanted to other rats.

CLINICAL CASES OF OSTEOGENIC SARCOMA FOLLOWING IRRADIATION

There are reports in the literature of twenty-four patients who developed bone sarcoma following exposure to irradiation. Seventeen of these tumors resulted from roentgenotherapy for tuberculous arthritis. One followed similar treatment for acute arthritis. In six cases, bone sarcoma followed exposure to radium.

Beck, in 1922, reported three cases in which bone sarcoma had developed within three to five years after roentgenotherapy. In the same year Marsch recorded two similar cases which had followed repeated roentgen exposures for tuberculosis of the knee five and seven years earlier. In 1924 Beck added two cases. Baumann described in 1927 a patient who had had tuberculosis of the elbow and who, six years after repeated x-ray treatments, presented a sarcoma of the distal end of the humerus. In 1929 Jaruslawsky described a round-cell sarcoma at the knee which had appeared eleven years after roentgenotherapy for tuberculous arthritis. Hanke and Neuhaus, in 1930, added one case of chondrosarcoma of the humerus, noted four years after repeated x-ray treatments of a tuberculous elbow. Küttner, in 1931, summarized the previously reported cases and added two. One of these was an osteosarcoma, found in the distal end of the femur which three years earlier had had repeated roentgen exposure during one year. His other case was a myeloid myeloma which appeared in the dorsal spine six and a half years after irradiation for tuberculosis of the same region.

Denks, in 1932, recorded a case of osteochondromyxosarcoma of the distal end of the femur, present six and a half years after excessive irradiation for tuberculosis of the knee. He also included Roedelius's case of sarcoma of the foot, noted ten years after roentgenotherapy for tarsal tuberculosis. Oehlecker's case, included in this same report, was of a spindle-cell sarcoma which was present six years after irradiation for an acute arthritis of the knee. Gruca, in 1934, reported a sarcoma containing cartilaginous and bony tissue. This tumor appeared five years after roentgen treatment of a tuberculous knee. Becker, in 1936, described a similar tumor which followed by ten years roentgenotherapy for tuberculous arthritis of a knee. Through accident an excessive amount was administered. In 1937, Hellner noted a polymorphocellular sarcoma which developed in a metacarpal bone five years after roentgenotherapy for tuberculosis of the wrist.

The most spectacular example of bone sarcoma resulting from irradiation is found in dial painters who repeatedly ingested minute amounts of radium, mesothorium, and radiothorium. Martland reviewed these cases and demonstrated radio-activity in all bones. Radiation necrosis was found chiefly in the jaw and in bones subject to weight and pressure. In five of eighteen fatal cases bone sarcomata were found. Martland states that in at least three living former dial painters sarcomata had been diagnosed.

Nørgaard, in 1939, observed in the proximal end of the tibia a fibrosarcoma which he considered due to intra-articular injection, eight years before, of ten micrograms of radium chloride for chronic arthritis of the knee. In the same patient a shoulder joint had been treated similarly. This joint showed evidence of radium necrosis of bone, but no tumor. Both areas showed signs of radio-activity even after eight years, that of the amputated portion being equivalent to three to four micrograms of radium.

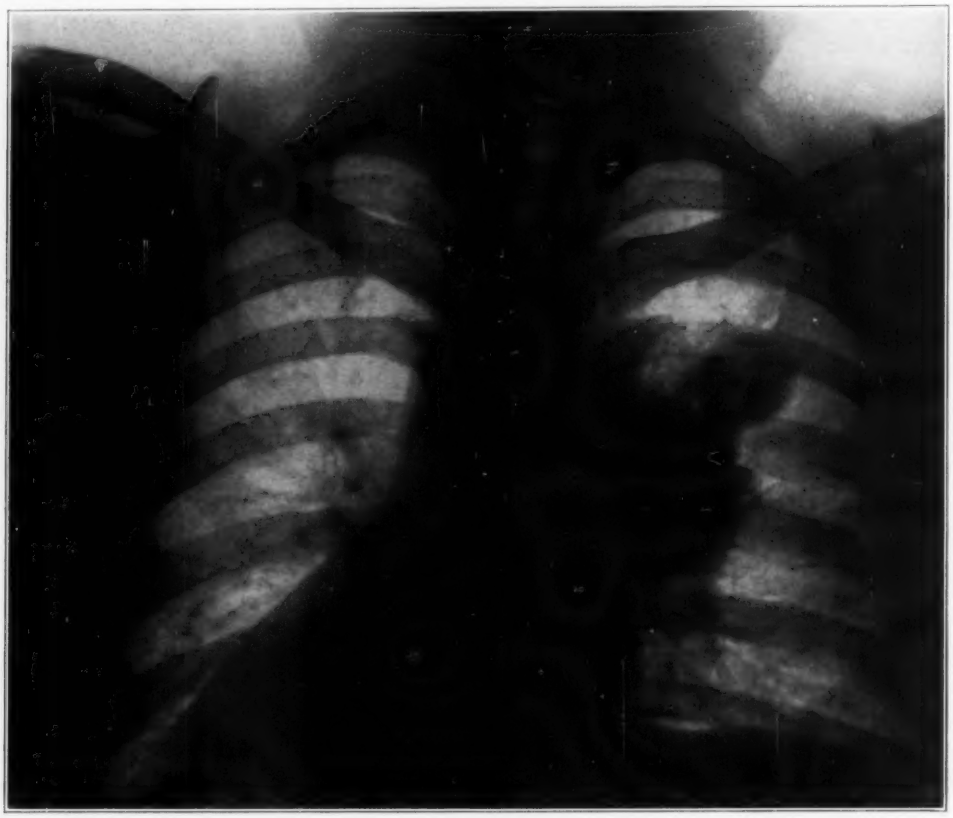

FIG. 1-C

Roentgenogram of chest ten months after thigh amputation shows metastatic tumor mass near the hilum of right lung.

REPORT OF CASES

CASE 1. H. R., a man, twenty-three years old, entered the University of Chicago Clinics October 30, 1942, complaining of pain in the right ankle, and foot-drop of three and a half weeks' duration. In 1936, when he was seventeen, he had had constant increasing pain in the right knee for which he had been admitted to a hospital. A diagnosis of giant-cell tumor of the proximal epiphysis of the tibia was made, and local

FIG. 1-D
Photograph of frontal section through tumor of fibula.

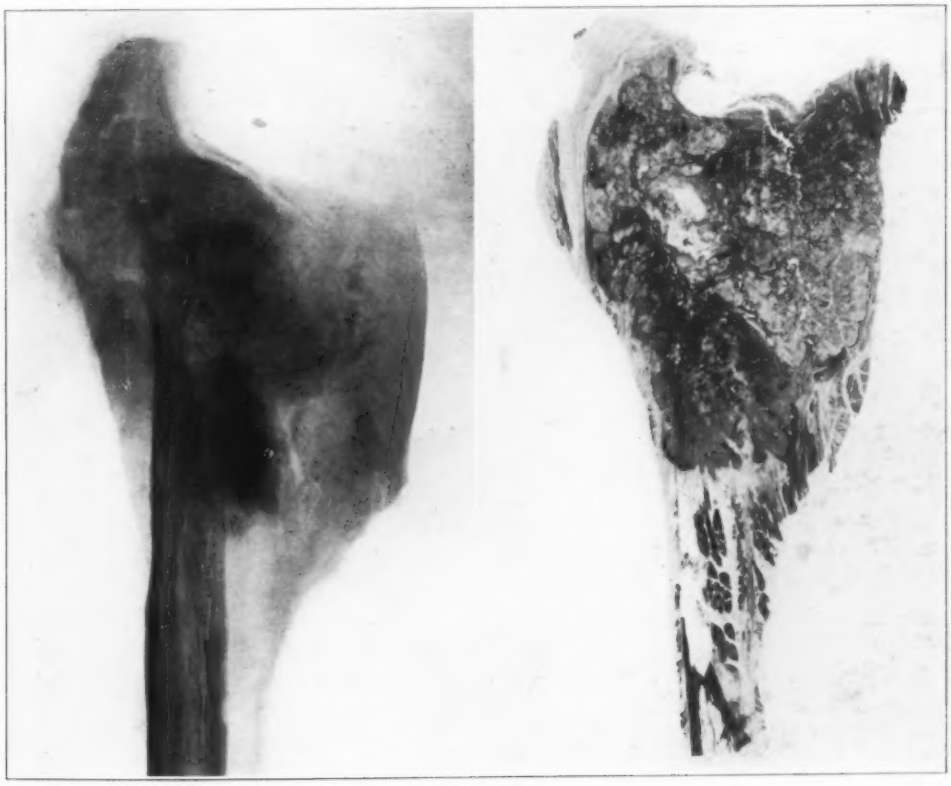

FIG. 1-E
Roentgenogram of frontal slice through tumor and photograph of the section show destruction of the shaft of the fibula and irregular ossification in the tumor.

excision of the lesion was done. Microscopic examination of the tissue (Fig. 1-A) showed benign chondroblastoma. From December 14, 1936, to May 20, 1937, he received over anterior, posterior, and lateral

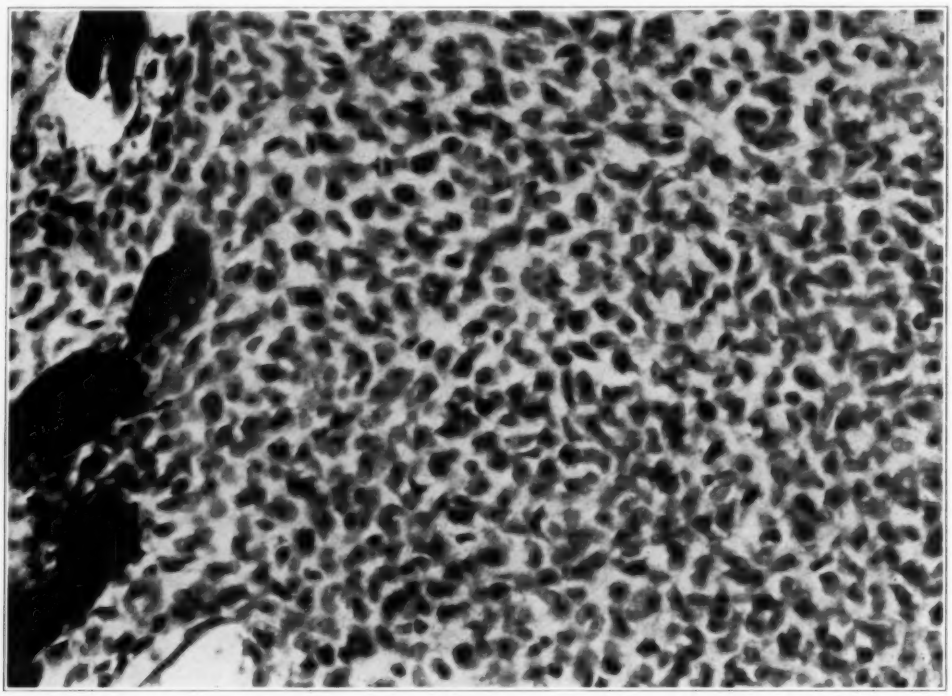

FIG. 1-F

Photomicrograph (×260) from periphery of tumor lobule shows closely packed immature chondroblasts.

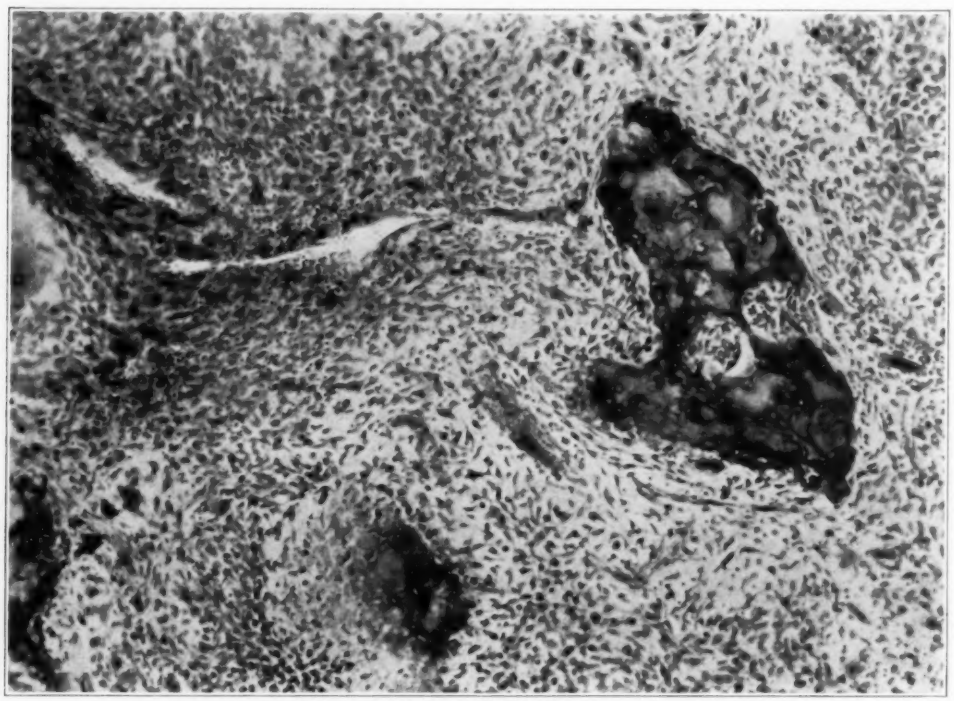

FIG. 1-G

Photomicrograph (×112) shows calcified tumor cartilage partly replaced by bone.

portals roentgen treatments each of 280 roentgen units in air filtered by 5 millimeters of copper and aluminum at 50 centimeters. Further therapy was administered during the next year so that a total of thirty-five treatments or 9800 roentgen units had been delivered to the surface. The patient remained well and without local symptoms until the onset of his present complaint. On examination, four years after the last roentgen exposure, there was evident on the anterior and lateral surfaces of the knee a band of pigmented, glazed, atrophic skin, six to ten centimeters wide, with telangiectasia but no ulceration. An anteromedial scar of 13.5 centimeters was well healed. The proximal end of the fibula beneath the telangiectatic skin was the site of a palpable non-tender mass. The dorsiflexor and peroneal muscles were paralyzed and the lateral aspect of the right leg and foot was hypalgic. The general examination was normal except for the findings in the right leg.

Roentgenograms (Fig. 1-B) showed irregular sclerosis at the site of the original tumor in the proximal tibial epiphysis, but no evidence of recent bone destruction. The shadow of the proximal 6 centimeters of the fibula was irregularly expanded by a mass of variable density, which partially obscured the bone. Laterally the mass had extended into the soft parts and medially it had encroached upon and narrowed the shadow of the lateral cortex of the tibia. In the distal 2 centimeters of the mass, there was marked increase in density in and around the fibular shaft. A diagnosis of sarcoma, primary in the proximal end of the fibula, was made. Roentgenograms of the lungs showed no evidence of metastasis.

FIG. 2-A

Case 2. Roentgenogram seven years after radium and x-ray therapy. The distal end of radius has been excised. There is sclerosis of distal end of ulna, but no evidence of tumor.

FIG. 2-C

Roentgenogram eleven years after irradiation, shows absorption of bone laterally at distal end of ulna.

FIG. 2-B

Roentgenograms ten and a half years after irradiation. Position of hand has been corrected by osteotomy of ulna.

On November 19, 1942, after the diagnosis of sarcoma had been confirmed by biopsy, a mid-thigh amputation was done. The wound healed without complication, and the patient was able to use an artificial limb eight weeks later. Ten months after the amputation, roentgenographic evidence of a metastatic tumor nodule appeared in the hilum of the right lung (Fig. 1-C). Two years after the amputation, the patient died. The amputation stump and the regional lymph nodes remained free of tumor recurrence and metastases.

Pathological Examination

The right lower extremity amputated in the mid-thigh showed the gross changes already described. On removal of the overlying soft parts, the proximal end of the fibula was found replaced by a tumor mass, measuring 8 by 6 by 3.5 centimeters. Mesially this mass encroached upon, but did not grow into, the lateral cortex of the tibia. Laterally and anteriorly it presented a lobulated surface. The peroneal nerve was incorporated in the mass. Frontal section (Fig. 1-D) through the tumor revealed a firm grayish-white mass which distally was bony hard, while proximally there were islands of bony density with surrounding firm glistening tissue of rubbery consistency. A roentgenogram of a slice through the tumor (Fig. 1-E) demonstrated almost complete destruction of the proximal 3 centimeters of the fibula. Irregular blotchy shadows were seen throughout the tumor. There was marked increase in density of the proximal end of the remaining shaft, and shadows of new bone formation radiated from it.

The proximal end of the tibia showed a depression anteriorly in the region of the operation done on the original benign tumor. Frontal section of this bone revealed no evidence of tumor tissue. Except for sclerotic margins, the defect had filled in with normal cancellous bone. The femoral and saphenous veins showed no evidence of tumor thrombi.

The section prepared from a frontal slice of the entire tumor of the fibula showed its irregular, lobulated structure. The peripheral portions of these lobules were composed of closely packed round or stellate cells, while centrally the cells were larger and the intercellular matrix more abundant (Fig. 1-F). Calcification and immature ossification were seen in the fibrous stroma between lobules and in the central areas of degeneration (Fig. 1-G). In the distal portion of the tumor, more immature ossification radiated from the fibular shaft.

Diagnosis: Chondrosarcoma, primary in the proximal end of the fibula.

FIG. 2-D

Photograph of resected distal three inches of ulna shows tumor mass projecting from lateral surface.

CASE 2. M. K., a female, when twenty-two years old, noted a painful swelling on the radial side of her right wrist. A diagnosis of benign giant-cell tumor was made with the aid of roentgenograms and tissue biopsy. Treatment by three applications of radium was given and later the patient received roentgenotherapy from several doctors. Ulceration and infection of the site occurred. A draining sinus necessitated removal of necrotic bone after three years. The total amount of irradiation by radium and by roentgenotherapy is unknown, but on entry here at the age of twenty-nine years the skin of the distal third of the forearm was atrophic, exfoliative, pigmented, and adherent to the underlying structures. The hand at this time deviated radially almost at a right angle to the forearm, due to loss of the distal portion of the radius (Fig. 2-A). There was sclerosis of bone in the distal end of the ulna, but no definite evidence of tumor. Osteotomy of the distal end of the ulna was done to correct the hand position, and an osteoperiosteal bone graft was added. A roentgenogram (Fig. 2-B) three years after the operation showed the deformity corrected. Four years after the osteotomy of the ulna—that is, eleven years after radium and roentgenotherapy—the patient noted a small tender swelling over the distal end of the ulna. The roentgenogram (Fig. 2-C) then showed an area of rarefaction laterally in the distal end of the ulna. Excision of the distal three inches of the ulna was done and the defect bridged by a tibial-bone transplant. Healing occurred, although there was superficial ulceration of the damaged skin. Ten years after the excision of this second tumor, there was no evidence of local recurrence or metastasis.

Pathological examination of the excised ulnar segment showed near its carpal end a firm mass, 2 by 1.5 centimeters, projecting from its lateral surface (Fig. 2-D). A microscopic section made through the entire specimen showed sclerotic bone of the ulna replaced by a densely cellular tumor. The cells were mainly

spindle cells with abundant collagen formation. A moderate number of multinucleated cells were present. Mitotic figures were easily found. In the central portions of the tumor, there was myxomatous degeneration, and tumor cartilage was observed (Figs. 2-E and 2-F).

Diagnosis: Fibrosarcoma with tumor cartilage.

FIG. 2-E

Photomicrograph (×44) shows fibroblastic tumor which replaced bone.

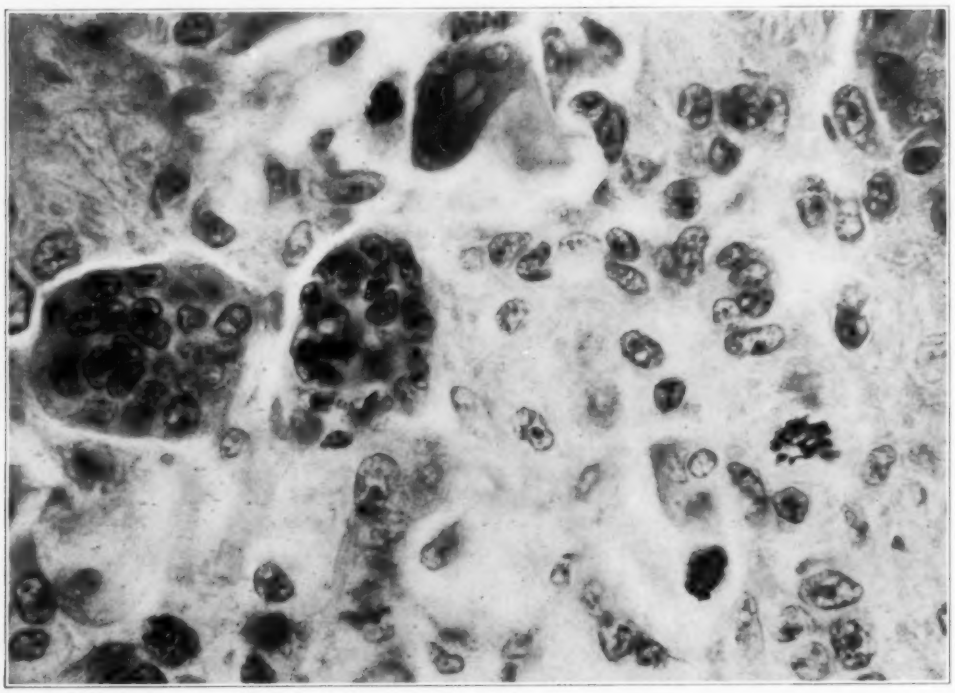

FIG. 2-F

Photomicrograph (×960) shows multinucleated cells and mitotic figures.

CASE 3. D. W., a woman of forty-nine, had had a radical mastectomy for carcinoma of the right breast twelve years before she was admitted to the Clinics in October 1943. Except for slight swelling of the right arm and temporary disability, she had had no postoperative difficulty. Four weeks after the mastectomy, roentgen-ray treatments were begun through anterior and lateral portals over the right chest and shoulder. Treatments were completed in September 1931. Accurate information on the amount of roentgenotherapy is not available. The patient estimates that she received twelve treatments during an interval of three months. She noted no skin alteration during or after therapy. She remained well until January, 1943—that is, eleven years after the last x-ray treatment—when she noted pain on pressure over the right side of the chest. Roentgenograms in May 1943 (Fig. 3-A) showed replacement of the anterior end of the right seventh rib by a mass of irregular density. The lung fields show no evidence of metastases. A total of 3000 roentgen units was given to the rib tumor in fifteen daily treatments of 200 roentgen units with 0.5 millimeters of copper.

When the patient came to the University Clinics in October 1943, examination showed a well-healed scar of the radical mastectomy. Anteriorly and laterally over the right side of the chest there was irregular brownish pigmentation, presumably from the recent roentgenotherapy. Near the costrochondral junction of the seventh rib a tender enlargement was palpable. No lymph nodes could be felt in the axilla or in the neck. Slight oedema was present, but no disability of the right arm.

On November 1, 1943, an oblique 20-centimeter incision was made over the anterior portion of the right seventh rib. The sixth, seventh, and eighth ribs were freed to the osteochondral junction, were cut posteriorly, and the pleural cavity was opened. A mass projecting on the posterior surface of the seventh rib could be palpated near the junction of the rib and its cartilage. The sixth, seventh, and eighth ribs with adherent portion of diaphragm were excised. The wound healed without complication. Six months later examination and roentgenograms disclosed no evidence of local recurrence or of metastasis.

Pathological Examination

The specimen (Fig. 3-B) of the seventh rib was 15 centimeters in length and included 1 centimeter of the

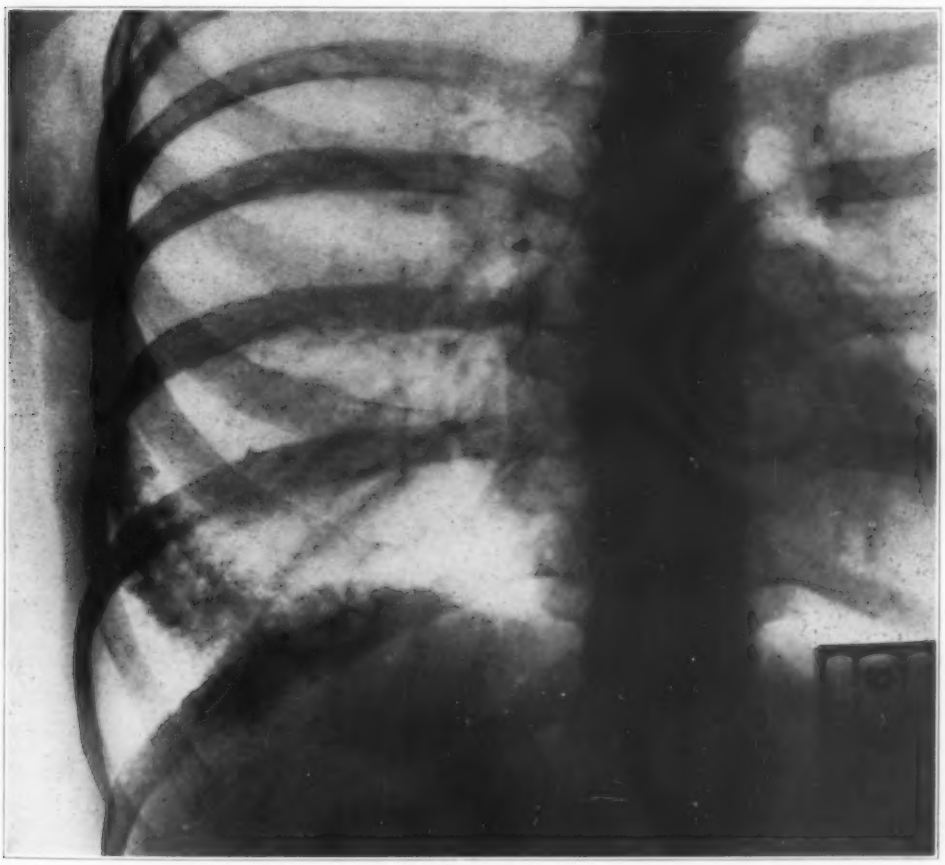

FIG. 3-A

Case 3. Roentgenogram of chest eleven and a half years after right mastectomy and x-ray therapy shows right seventh rib replaced anteriorly by a mass with irregular shadows of new bone.

FIG. 3-B

Superior and lateral surfaces of resected seventh rib. Pleural surface shows subpleural nodule and attached diaphragmatic muscle.

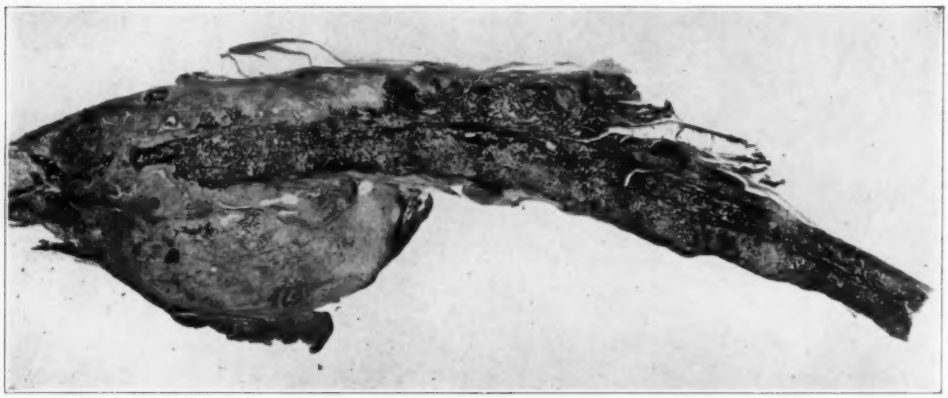

FIG. 3-C

Photograph of microscopic section through entire specimen.

costal cartilage. The distal 9 centimeters was enlarged by a firm mass which projected 0.5 to 1 centimeter from the lateral surface. The mesial surface was thickened and broadened along its entire length. At the anterior end a firm mass, 2 by 4 by 4 centimeters, projected from the pleural surface and was adherent to a portion of the diaphragmatic musculature.

A microscopic section was prepared through the entire length of the involved rib (Fig. 3-C). This demonstrated the intramedullary and subperiosteal extent of the tumor. The subpleural nodule with ad-

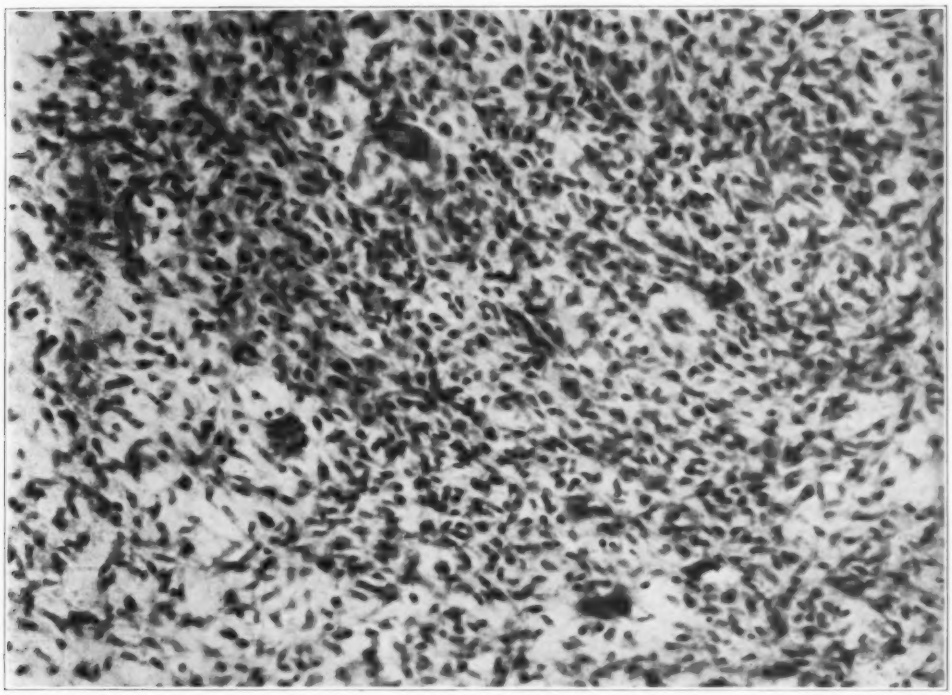

FIG. 3-D

Section (×200) from periphery of subpleural nodule shows closely packed round and stellate chondroblasts and multinucleated cells.

herent muscle was seen near the osteochondral junction. The characteristic tumor cells were best seen in this subpleural nodule, where peripherally they were small and flattened with little intercellular substance (Fig. 3-D). Centrally the cells were larger and stellate, and there was much intercellular hyaline matrix which showed granular calcification and ossification (Fig. 3-E). Other subperiosteal regions showed essentially the same picture. The cortices of the rib could be identified. Most of this bone was necrotic, as a result either of the recent roentgenotherapy or of interference with the blood supply by the tumor. Neoplastic bone had in many areas been laid down on the surface of old bone trabeculae (Fig. 3-F).

Diagnosis: Chondrosarcoma, primary in the seventh rib.

DISCUSSION

The three tumors here reported are regarded as sarcomata, produced by irradiation therapy for earlier neoplasms in the same regions. There is the possibility that they represent recurrence or metastasis of the original tumors. In Cases 1 and 2 the initial lesions were considered to be benign epiphyseal tumors. Apparently surgical operation and irradiation effected a cure of this disease in each case. Against the idea that the subsequent sarcoma represents a regional recurrence or latent metastasis of the primary tumor is the long period before sarcoma was evident. In Case 1, seven years and in Case 2, eleven years elapsed between eradication of the benign tumor and appearance of sarcoma. Also against local recurrence is the fact that in each case the sarcoma developed not at the site of the original tumor, but in previously normal bone. Latent metastasis from the original growths can hardly be the explanation, since the second tumors are clinically and histologically different from the original ones. Moreover, irradiation sufficient to destroy the first neoplasm should have destroyed any metastases in the same field.

Sarcomatous change in benign giant-cell tumor has been described. Evidence of such malignant change has usually been obvious within one or two years at the site of the original tumor. The possibility may be noted here that so-called late malignant degeneration of benign giant-cell tumor treated by irradiation may represent in some cases sarcoma induced by irradiation.

It is unlikely that Cases 1 and 2 are instances of malignant transformation of giant-cell tumor.

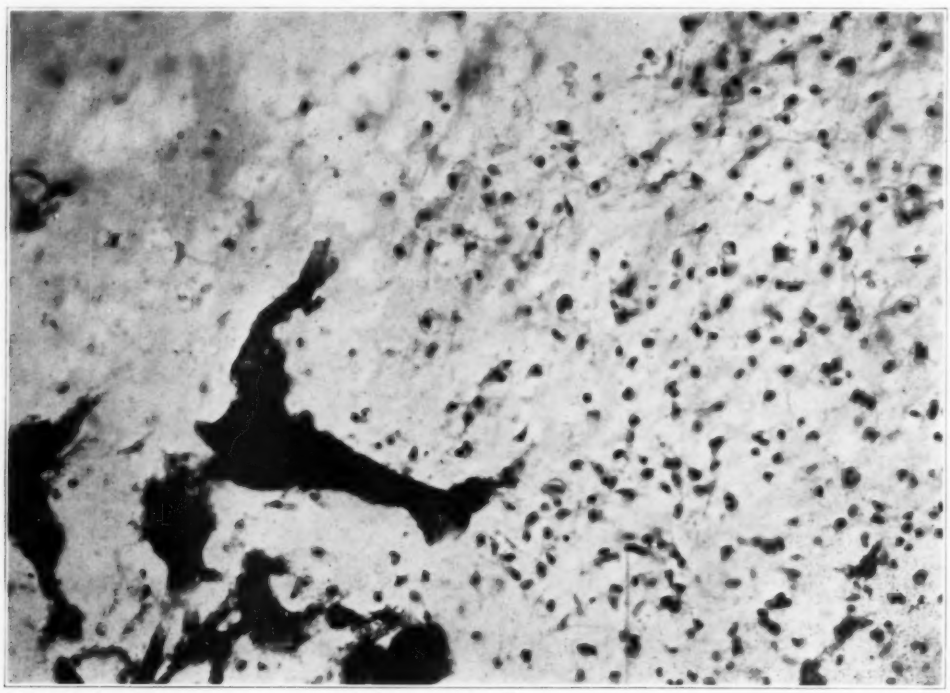

FIG. 3-E

Section (×200) from central portion of nodule shows necrotic cartilage with calcification and ossification.

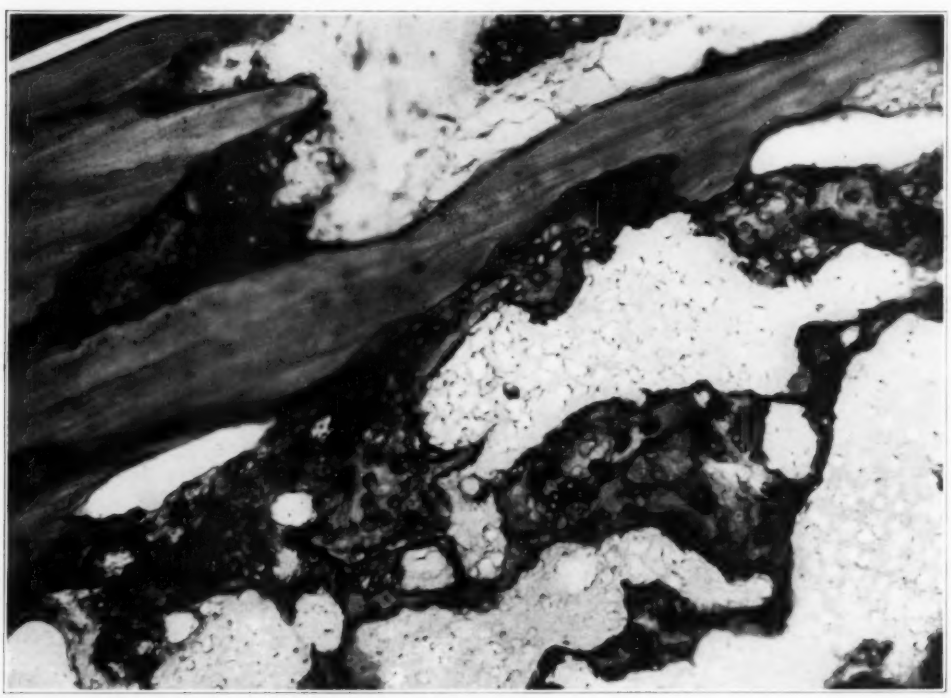

FIG. 3-F

Section (×100) from medulla of rib shows necrotic old bone trabeculae with ossifying cartilaginous tumor.

In Case 3, no question of regional recurrence or latent metastasis can be raised, because the primary tumor was carcinoma of the breast and the late rib tumor a chondrosarcoma. There can be some doubt that the postoperative irradiation caused the rib tumor, since apparently relatively little irradiation was used. Also the ribs are a common site for chondroma and chondrosarcoma, which may grow slowly and not produce symptoms for a long time. However, chest roentgenograms made at the time of mastectomy, though not now available, were reported as normal. It is probably more than coincidence that chondrosarcoma developed in a rib within the field irradiated for carcinoma of the breast.

The presence of chronic infection in all the early cases of roentgen sarcoma of bone led most authors to the conclusion that irradiation of chronically inflamed tissue was responsible for tumor formation. Lacassagne and others stressed also the importance of infection and chronic irritation in experimental production of irradiation sarcoma. Although Schürch and Uehlinger, and later others, showed that irradiation by roentgenotherapy or radium alone produced bone sarcoma in a fair percentage of animals, there have been few reported clinical cases. Martland's cases of poisoning by radium ingestion and Nørgaard's case of bone sarcoma after the treatment of chronic arthritis by intra-articular radium chloride are the only recorded irradiation sarcomata of bone where infection was not present in the irradiated field. In this present report, Case 1 and Case 3 showed no infection. In Case 2 there was local bone infection, following ulceration of the skin, due to roentgen and radium therapy. This infected tissue was never irradiated, and the roentgen sarcoma arose in bone which had not been infected.

It is true that occasionally malignant tumors develop in chronically infected bone, not subjected to irradiation. These tumors, however, are usually carcinomata, developing in chronic ulcers or in epithelized sinus tracts. Sarcoma formation in chronically infected bone not exposed to irradiation is extremely rare. Kaufmann mentions one such case, but it is open to question.

Most studies on the effect of irradiation upon the skeleton have been concerned with alterations in hematopoietic marrow and with disturbances in epiphyseal cartilage. The changes in osseous tissue have received less attention. Phemister showed that radium implanted in bone produces extensive aseptic necrosis of regional bone. Replacement of the dead by living bone occurs more slowly than in other forms of aseptic necrosis, and hence fractures are apt to occur. Dense fibrous scar eventually occupies the marrow spaces. Whether sarcomata develop from the fibrous scar or from damaged reticuloendothelial cells is not known.

One of the most interesting facts about roentgen or radium-induced sarcomata of bone is the large proportion of cartilage-forming tumors. This is true of sarcomata produced in experimental animals, as well as in human beings. Unfortunately the histological description of some of the earlier cases is not detailed enough to permit of classification as to histological type. Nevertheless, of the twenty-four cases recorded, nine are undoubtedly cases of chondrosarcoma. Cases 1 and 3 of this report are typical chondrosarcoma. Case 2 shows myxomatous degeneration and cartilage formation, but the greater part of the tumor is a typical fibrosarcoma. Such a tumor is difficult to classify accurately. The reason for the predominance of sarcomata of cartilaginous nature is not known. It may be that undifferentiated mesodermal cells or reparative scar tissue, when stimulated to neoplastic growth by irradiation, take on cartilage-forming ability.

Roentgenotherapy was used in eighteen of the twenty-four recorded cases of irradiation bone sarcoma. In all of these the total irradiation was great. Many reports do not record the amount accurately, but from the descriptions of changes in the skin and other soft parts it is evident that severe tissue damage was produced. The roentgenotherapy in all of them was administered in repeated doses, spaced over one to five years. In Case 1 of this report 9800 roentgen units were delivered to the surface in fractional doses during

one year. The proximal end of the fibula, it can be estimated, received approximately 80 per cent. of that dose. The secondary radiation within bone may increase the effect within and about that tissue. In Case 3 roentgenotherapy produced no noticeable skin alteration. Practically all that was administered can be assumed to have been delivered within the ribs, since radical mastectomy had removed all overlying musculature. It may be that bones rich in hematopoietic tissue and reticulo-endothelial cells are more prone to develop sarcoma than are bones which have a greater proportion of fatty marrow. It may be also that predisposition of the individual to neoplastic growth is a factor in development of irradiation sarcoma. Warren and Ehrenreich have shown in cases with multiple tumors that there exists an individual susceptibility to cancer.

The time required for development of sarcoma after irradiation of bone is long. In the cases in the literature, the shortest interval was three years and the longest eleven years. In the three cases added here, sarcoma was recognized four, eleven, and eleven years, respectively, after the final exposure to irradiation. The median for all reported cases is six years.

SUMMARY AND CONCLUSIONS

1. Twenty-four cases of bone sarcoma which followed x-ray or radium irradiation of bone are reviewed. All except six of these occurred in association with chronic joint infection.

2. Three cases are added which are regarded as bone sarcoma, resulting from irradiation of bone for earlier independent tumors. Two are chondrosarcoma, and one is fibrosarcoma with tumor cartilage.

3. In all cases except one, the amount of irradiation was large and was administered in fractional doses over a long period.

4. The interval between irradiation and recognition of irradiation-produced sarcoma is long. The median time in reported cases is six years.

5. Chondrosarcoma occurs more frequently among irradiation-produced sarcomata than in other bone tumors.

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TREATMENT OF BENIGN GIANT-CELL TUMORS BY RESECTION OR EXCISION AND BONE GRAFTING *

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The complete excision of benign giant-cell tumors results in cure. The site and extent of the tumor are important factors when deciding on the type of treatment. Since such tumors are osteolytic in nature, fracture is common. This is especially true in weight-bearing bones. In the majority of cases, the tumor occurs in the region of a joint. It is the purpose of this presentation to discuss the experience with resection and with excision and bone grafting for benign giant-cell tumor at the Mayo Clinic. Although excision of the tumor without bone grafting may result in a cure, ossification of the blood-filled cavities is slow and convalescence is prolonged unduly. In certain cases, complete excision of the tumor and bone grafting result in a more rapid cure without deformity or disability, and restore strength and function of the extremity in a shorter time.

Because of the size and site of some benign giant-cell tumors, irradiation therapy is the only treatment that can be employed. Interesting cures have resulted from the use of roentgenotherapy alone. In Case 8, reported later in this paper, such a result was obtained. A combination of surgical treatment and roentgenotherapy may be employed, but this treatment is associated with a certain amount of danger (Case 7); and surgical treatment only, wherever it is possible, is preferable. Preoperative irradiation may produce damage of tissue and atrophy; I have observed patients so treated, in whom the operative scar broke down, an ulcer formed, and the graft was lost. One must keep an open mind as to the relative value of the methods of treatment and employ that which, in his experience, has proved to be the best in the individual case.

The evaluation of any type of treatment depends on a correct diagnosis, on judgment in the selection of patients, on skill in carrying out the treatment, on a careful review of the history, on the clinical, roentgenographic, pathological, and surgical findings, and on the patient's progress for several years afterward. In studying a series of forty cases of this type of tumor, in which excision of the tumor and bone grafting were performed during a period of thirty-one years, 1913 to 1943 inclusive, I have endeavored to adhere to these criteria.

HISTORY

In 92 per cent. of the forty cases, the patients were between ten and fifty years of age; the average age was 28.7 years. The youngest patient was eight years of age, and the oldest was sixty-three years. A history of a single injury was elicited in twenty-one cases (52 per cent.), and multiple injuries had occurred in two cases (5 per cent.). In four cases (10 per cent.), it was definitely stated that injury had not occurred; and in thirteen (32 per cent.), trauma was not mentioned in the history. In thirty-two cases (80 per cent.), symptoms had been present for less than three years; in twenty-three cases (58 per cent.), symptoms had been present for less than one year; and in eight cases (20 per cent.), symptoms had been present for three years or more. The average duration of symptoms before operation was 23.5 months. Treatment prior to consultation and operation at the Clinic had consisted of immobilization, diathermy, elimination of foci of infection, arthritis vaccines in five cases (12 per cent.), aspiration in six cases (15 per cent.) in two of which irradiation also had been employed, irradiation alone in four cases (10 per cent.), excision and

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irradiation in one case (2.5 per cent.), and excision and bone grafting in two cases (5 per cent.). In two (5 per cent.) of the cases, a diagnosis of sarcoma had been made and amputation had been advised.

DIAGNOSIS

Although the diagnosis of benign giant-cell tumor usually can be made on the basis of the history and the clinical and roentgenographic findings, an occasional error may occur. Microscopic examination is more reliable, and has seldom been in error. Although Herendeen admitted that an error may occur in the roentgenographic diagnosis, he expressed the opinion that routine biopsy is unnecessary, if the clinical history and the physical and roentgenographic findings are characteristic. However, in my experience, these so-called characteristic clinical and roentgenographic features are untrustworthy. Herendeen said further that, if the diagnosis cannot be made without microscopic examination, it is not uncommon to find that the microscopic findings are as uncertain as the roentgenographic findings. Furthermore, he said that biopsy may result in infection, dissemination of tumor cells, and acceleration of growth of the tumor, owing to breaking down the natural barrier around it. Operations which are performed with the aid of a tourniquet, such as resection of the involved portion of bone and complete excision of the tumor by curettage followed immediately by cauterization, and microscopic examination of frozen sections have practically eliminated such complications. There are some cases in which the pathologist has not been given the true tumor tissue, or he has been given such small portions of tissue that an accurate diagnosis was impossible. A punch biopsy is useful in those cases in which the tumor is situated in inaccessible regions and in cases in which exposure is dangerous. Although this procedure is employed at times at the Clinic, it is not used routinely. Close cooperation between the pathologist and surgeon at the time of the operation leads to the correct diagnosis and prompt treatment. The differential diagnosis of benign giant-cell tumor and malignant giant-cell sarcoma cannot be made on the basis of roentgenographic interpretation alone. Adequate exposure and the removal of a block of tissue will enable the surgeon and the pathologist to examine the gross specimen and obtain several sections for microscopic examination. Should there be any doubt that the lesion is benign, the wound should be closed and the pathologist given additional time. This sometimes is necessary in cases in which a previous operation has been performed, in cases where irradiation has been employed, and in cases in which the tumor is infected; it is rarely necessary if the patient has not received treatment previously.

SELECTION OF CASES

In the usual case in which excision and bone grafting are performed, the tumor is situated in an extremity; and, when such surgical procedures are carried out correctly, they give excellent results. After the roentgenographic examination has demonstrated the extent of involvement, and has excluded evidence of recognizable metastatic involvement in the thorax, the surgeon decides whether resection of the involved portion of bone or excision of the tumor with curettage and cauterization is indicated.

OPERATIVE PROCEDURE

Curettage of a giant-cell tumor should consist of complete excision; in order to accomplish this it is necessary to have a dry field and an opening large enough so that the size of the lesion can be determined and every particle of tumor tissue removed. Complete removal is necessary. Furthermore, the surgeon must select a bone from which the proposed graft is to be obtained; usually the graft is taken from the tibia, fibula, ilium, or from a sound portion of the involved bone. Although autogenous bone grafts are preferred, homogenous grafts have been used to fill huge defects. As hemorrhage may cause

serious complications in cases in which it is impossible to use a tourniquet, the surgeon should be prepared to pack the cavity. When such a procedure is necessary, a gauze pack impregnated with petrolatum and sulfathiazole is used, and the wound is sutured in layers. The pack may be left in place for a week, and the operation may be completed at the second stage. Massive resection of the involved bone is usually performed in cases in which the tumor is situated in the radius, ulna, or fibula. When the tumor is large and involves the tibia or femur, large bone grafts are required. In such cases, the bone struts and shavings are generally obtained from the tibia.

The best results are obtained in cases in which the cavity is packed firmly with autogenous bone, and when complete rest is assured by immobilization of the extremity in a plaster-of-Paris cast. In cases in which the tumor is situated in the region of the knee or the ankle, weight-bearing should be avoided until the roentgenographic examination discloses sufficient deposition of bone to stand the stress and strain that will be required. In those instances in which the articular cartilage is exposed, the use of supporting struts is advisable, and it is well to fill the interspaces with shavings and cancellous bone. An electric bone saw is employed for the removal of the struts, and a sharp chisel and curette are used to obtain shavings. After the

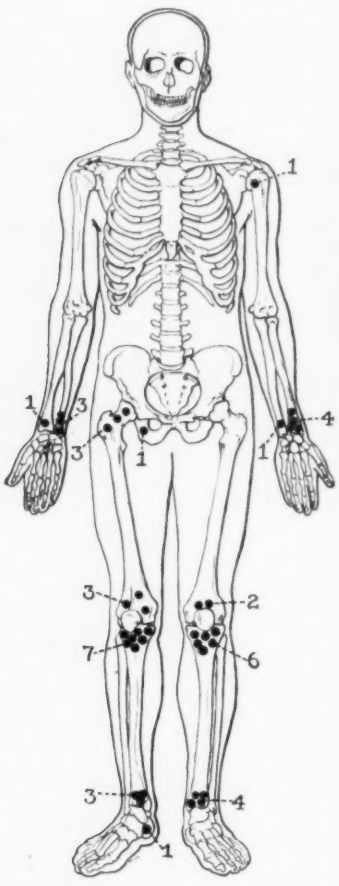

FIG. 1

Distribution of benign giant-cell tumors; the figures indicate the number of instances in which tumors occurred at the respective sites in a series of forty cases.

FIG. 2

Case 1. *a:* Benign giant-cell tumor expanding lower part of left ulna. *b:* Bone graft in position twenty-three years after operation. *c:* Photomicrograph (×85) of the tumor.

cavity has been packed with bone, the periosteum, whenever possible, is sutured; and the wound is closed snugly in layers. Bloody drainage should be avoided, as it may lead to infection or to osteomyelitis, in which case the grafts may be lost. Frank infection did not occur in any case in this series, although several patients had serous discharge for short periods, or ulcers in incisions as a result of previous irradiation. In the past, writers have emphasized the dangers of hemorrhage, shock, and infection. Modern aseptic surgery has to a large extent eliminated these complications.

RESULTS

In the twenty-six years from 1913 to 1938 inclusive, excision and bone grafting were performed in eighteen cases, and in the five years from 1939 to 1943 inclusive, these procedures were followed in twenty-two cases. In one patient, whose tumor was very extensive and cellular in type, and had recurred, an amputation was required. This patient is living more than five years after the onset of symptoms, and is wearing an artificial limb. Routine roentgenographic examination of the lungs did not disclose any evidence of metastasis in this series of cases. The sites of involvement in this series are shown in Figure 1.

Of twenty-six patients who had not undergone a previous operation, twenty-four obtained good functional results, and two required second operations. One of these patients required an amputation; the other was operated on elsewhere, and the result evidently was satisfactory. Of the four patients who had received only irradiation therapy of unknown degree before coming to the Clinic, all obtained good functional results. Of the three patients who had undergone an operation before they came to the Clinic, all obtained good functional results. Of three patients who previously had undergone some form of operation, and, in addition, had received irradiation therapy, also of unknown degree, all obtained good functional results.

Therefore, of the forty patients in this series, thirty-eight, or 95 per cent., obtained good functional results, and two, or 5 per cent., did not.

Three of the forty patients have died. One of these died suddenly of cerebral hemorrhage, one year after operation. One died of chronic inflammation of the intestine and anaemia more than a year after operation, and the family physician said that there was no evidence of metastasis of the tumor. The third patient died suddenly, nearly seven years later, four days after the onset of pneumonia. The family physician reported no evidence of metastasis.

REPORT OF CASES

CASE 1. A woman, thirty years of age, came to the Clinic on June 30, 1913, because of aching pain and swelling of the left wrist of two years' duration. There was no history of trauma, and she had had no previous treatment. On July 4, 1913, the lower end of the left ulna was resected and a tibial bone graft was inserted. The pathologist reported that the lesion was a benign giant-cell tumor (Fig. 2, *a*). Twenty-three years later, the roentgenographic examination showed that the bone graft was in good position and that union had occurred. In March 1944, or thirty-one years later, the patient reported that she had good function of her arm.

CASE 2. A woman, twenty years of age, came to the Clinic on April 25, 1927, because of pain, swelling, and local heat, which had been present in the right leg for nine months. There was no history of trauma. The severity of the symptoms had increased gradually, and she had been told she had a cancer of the bone. Clinical and roentgenographic examination revealed a giant-cell tumor of the upper part of the right tibia (Fig. 3, *a* and *b*). The lesion had destroyed practically all of the upper part of the tibia. On April 27, 1927, soft tissue was removed by curettage, and numerous bone grafts from the flat internal surface of the tibia were placed in the cavity, after which the periosteum was sutured snugly. Then a cast was applied. The pathologist reported that the lesion was a benign giant-cell tumor. The convalescence was uneventful. Seventeen years later, the patient reported that she had not had any difficulty with her leg and that the function was good.

CASE 3. A woman, thirty-eight years of age, came to the Clinic on April 8, 1929, because of pain,

FIG. 3

Case 2. *a:* Anteroposterior roentgenogram of upper part of right tibia, showing benign giant-cell tumor; *b:* lateral roentgenogram showing tumor. *c:* Anteroposterior roentgenogram, showing bone graft in position twelve and a half years after operation; *d:* lateral roentgenogram made the same day.

swelling, and local heat of the left forearm of seven and a half years' duration. In the six weeks before she came to the Clinic, irradiation therapy had been employed twice, and operation had been advised. On April 11, 1929, operation revealed that the tumor had already broken through the cortex of the bone (Fig. 4, *a*). The tumor, which consisted of reddish jamlike material, was removed entirely by curette and chisel. A bone graft from the left fibula was fitted into the defect and was held in place with beef-bone screws (Fig. 4, *b*). A cast was applied from the fingers to the middle of the humerus. The pathologist reported that the tumor was a benign giant-cell tumor. The convalescence was uneventful and the patient returned home on the twenty-fourth day after operation. Six years and nine months later, she suddenly became ill with pneumonia, and died after four days. She had had good function and no trouble with her arm after the operation.

FIG. 4

Case 3. *a:* Benign giant-cell tumor that has destroyed the lower part of the left radius, and has extended into the soft tissues. *b:* Bone graft held in place with a beef-bone screw.

CASE 4. A woman, thirty years of age, came to the Clinic because of pain in the right hip of two years' duration. A diagnosis of arthritis had been made. Traction treatment had been employed, and she had used crutches. Later a tumor had been discovered. There was a history of trauma fifteen years before she came to the Clinic. Clinical and roentgenographic examination resulted in a diagnosis of giant-cell tumor or cyst (Fig. 5, *a*).

FIG. 5

Case 4. *a:* Benign giant-cell tumor, which has caused extensive destruction of the head and neck of the right femur. *b:* Appearance of involved bone three months after excision of the tumor and insertion of a bone graft.

FIG. 6

Case 5. *a* and *b*: Anteroposterior and lateral roentgenograms, showing benign giant-cell tumor which has caused extensive destruction of lower part of right femur. *c* and *d*: Anteroposterior and lateral roentgenograms, showing bone grafts in position one year after operation.

Excision of the tumor and bone grafting were performed on June 28, 1938. Bleeding was controlled with hot packs, and the wound was swabbed with a solution of zinc chloride. Bone chips obtained from the right ilium and right tibia were packed into the cavity. A spica cast was applied. The pathologist reported that

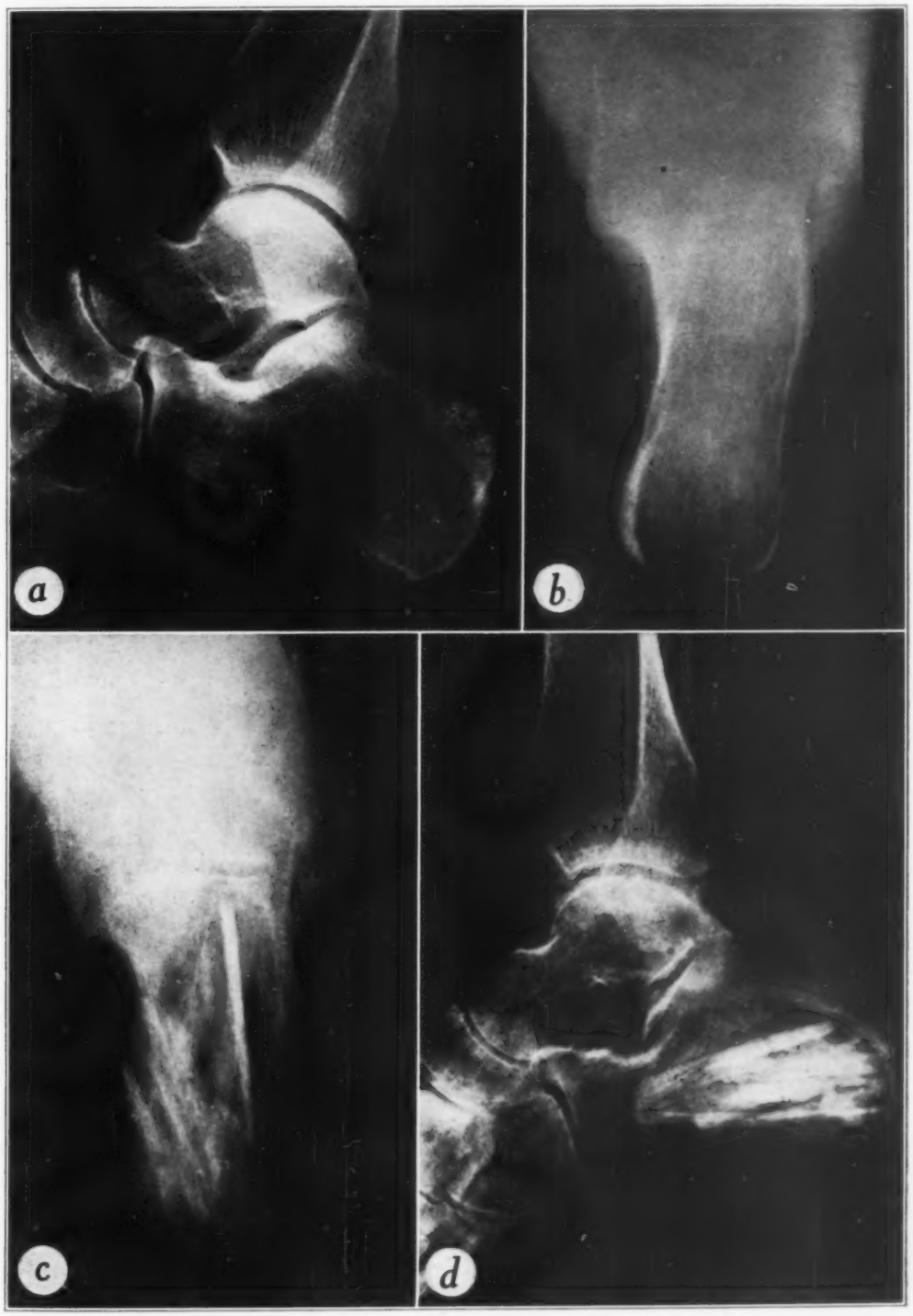

FIG. 7

Case 6. *a:* Lateral roentgenogram of right os calcis, showing benign giant-cell tumor which has caused extensive destruction; *b:* dorsoplantar view of os calcis, showing tumor. *c:* Dorsoplantar view, showing bone grafts in position; *d:* lateral roentgenograms, showing bone grafts in position.

FIG. 8

Case 7. *a*: Anteroposterior view, showing giant-cell tumor of the left ilium. *b*: Anteroposterior view, taken seven years after excision of the tumor and irradiation, shows calcification of the tumor.

the tumor was a benign giant-cell tumor. More than five years later, the patient reported that she had good function and was working.

CASE 5. A woman, thirty-four years of age, came to the Clinic on January 28, 1939, because of swelling of the lower part of the right femur. The swelling had been present for one year. It had been associated with pain and a local increase in temperature. There was no history of trauma. A clinical diagnosis of giant-cell tumor was made (Fig. 6, *a* and *b*). The roentgenologist suggested the possibility of sarcoma. On January 30, 1939, the tumor was excised, and bone grafts were inserted. The periosteum was then sutured, and the wound was closed in layers. A cast was applied. The pathologist reported that the tumor was a benign giant-cell tumor. Convalescence was uneventful and the patient left the Hospital on the twenty-fifth day after operation. More than five years later, the patient said that the functional result was good.

CASE 6. A woman, forty-two years of age, came to the Clinic in October 1939, because of trifacial neuralgia. In the course of the examination she complained of occasional pain in the region of the right os calcis. A clinical and roentgenographic diagnosis of giant-cell tumor or cyst was made (Fig. 7, *a* and *b*). On November 1, 1939, the tumor was removed and bone grafts were inserted. The pathologist made a report of benign giant-cell tumor. Four and a half years later, the patient said that the function of the involved limb was good. She had no pain and was able to do her usual work.

CASE 7. A married woman, aged twenty-six years, admitted to the Clinic on June 8, 1937, complained of pain and swelling in the left buttock of four months' duration. A malignant lesion of the left ilium was suspected, and an exploratory operation was advised. On June 16, 1937, the tumor was excised; on examination of the tissue, the pathologist found that it was a benign, foreign-body, giant-cell tumor. The patient was given nine low-voltage roentgen treatments postoperatively, and calcification occurred.

In January 1941, the patient was delivered of a normal baby and complete calcification had occurred at the site of the tumor as shown in the roentgenogram (Fig. 8, *b*). Seven years after institution of treatment, the patient is in good health.

CASE 8. A man, twenty-nine years of age, was seen May 29, 1936, at which time he stated that about March 25 he had noticed soreness of his left shoulder, following exposure to cold. Pain had increased gradually, and he had been given physical therapy and roentgenotherapy for subdeltoid bursitis.

Roentgenograms of the left shoulder revealed a large area of destruction of the lateral aspect of the left scapula, just medial to the scapular neck. The roentgenologist made a diagnosis of metastatic malignant lesion. On June 16, 1936, the tumor was explored and tissue removed. The pathologist reported that the tissue came from a vascular giant-cell tumor. (This tissue has been re-examined recently by Dr. A. C. Broders who corroborated the diagnosis of benign giant-cell tumor.) It was the opinion of the surgeon that the tumor could not be removed unless a forequarter amputation was performed. Three low-voltage roentgen treatments were given. The patient had good motion of the left arm, and was free of symptoms in two months, at which time roentgenograms showed that the tumor was undergoing sclerosis. Six months later, further roentgenograms showed practically complete calcification of the tumor. The patient is living and well eight years after the biopsy and exploratory operation.

COMMENT AND SUMMARY

This paper is based on a series of forty cases of benign giant-cell tumor of bone, in which excision of the tumor and bone grafting were employed. The history, as well as the clinical, roentgenographic, and microscopic findings, and the follow-up data have been reviewed in all forty cases, and the diagnosis of benign giant-cell tumor has been confirmed. Massive resection and excision by curettage and cauterization appear to be safe methods of eradicating the tumor. The resultant cavities have been filled with autogenous bone, which stimulates rapid formation of bone, lessens the danger of collapse from fracture, and tends to prevent deformity and disability. Excision of the tumor and bone grafting is a safe procedure in properly selected cases, and it tends to prevent deformity and disability.

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DISCUSSION

DR. NICHOLAS S. RANSOHOFF, New York, N. Y.: I would like to congratulate Dr. Hatcher on his splendid presentation, and report another case. This is a case of which Dr. Gill knows, and which I think Dr. Moore saw and treated. The lesion resembled a bone cyst in the upper end of the humerus. The patient was treated with massive doses of roentgenotherapy, and was operated upon by me last October. Much to my surprise, Dr. Jaffe's pathological report was fibrosarcoma of the bone. It has grown to large size. There is an extensive recurrence locally, but no axillary glands are involved. The chest x-rays have been reported negative. We now wish to disarticulate the patient's arm, but his parents refuse to have it done. It will be a pleasure to have Dr. Hatcher include this case with his.

DR. CARL E. BADGLEY, Ann Arbor, Michigan: As one reviews the literature on benign giant-cell tumor and giant-cell sarcoma, or the malignant variation of giant-cell tumor, much confusion is apparent. Various forms of therapy have been employed in the treatment of the benign tumor. In our own Clinic, the Department of Roentgenology in 1936 reported the treatment of forty cases of benign giant-cell tumor. The statistical report was of practically no value, because, as we classified these cases into various groups according to treatment, there were too few in each group to be of any value. It has been our opinion in the study of the cases we have followed since that time, that, in the treatment of giant-cell tumor, one must make up his mind whether he will employ roentgenotherapy or surgery. A combination of roentgenotherapy and surgery has given us poorer results than either alone. Eighty-six per cent. had good results by surgery alone; 85 per cent. by roentgen ray alone; 40 per cent. had good results from preoperative radiation, surgery, and then postoperative radiation, and 60 per cent. were failures from this treatment.

I want to emphasize that radiation following operation and the employment of a bone graft is a dangerous procedure. It may well prevent creeping substitution in the bone graft, and may interfere with healing.

I want to compliment Dr. Meyerding for the practical points in his talk. He has selected forty, or 28 per cent., of the giant-cell tumors, because they were benign and were treated by surgery. That gives us something to work with. A comparison of the figures from the Mayo Clinic and other clinics will give us ultimately a basis for selecting treatment. His success of 95 per cent. with surgery gives us something by which we can measure other forms of treatment.

Incidentally, the one failure we had—and I say this in justification of x-ray therapy—was a patient upon whom we operated, intending to do a bone graft. There was so much bleeding that we closed the wound, and finally convinced the X-Ray Department that they should give roentgenotherapy prior to surgery; under roentgenotherapy the patient recovered. That was an achievement with x-ray where surgery had failed.

DR. ALBERTO INCLÁN, Havana, Cuba: In my own experience the treatment of choice has always been complete resection whenever possible. Of course, the giant-cell tumor may be localized in places where we cannot use this type of radical surgery. In the cases where we have to preserve joint function, as in most of the cases Dr. Meyerding has shown us, we do a more or less complete excision, with bone grafting. We have had recurrence of the tumor twice after the use of this method. That is why I prefer complete resection, which has never been followed by recurrence in our cases. I have noticed that the patients treated by curettage and cauterization have shown the greatest number of recurrences. In the pathological examina-

tion of these recurrences we have found a malignant change in the histological aspect of the lesion, showing more or less marked signs of local malignancy in the stroma, such as hyperchromatism, mitosis, and sometimes increased vascularity of the stroma. In other words there has been a definite change in the histological aspect of the original benign lesion, without the appearance of a true sarcoma. In dealing with this type of case, I believe complete resection should always be done.

In 1940 I published a paper reviewing thirty cases of giant-cell tumor, and I made it very plain that, even in these cases with local signs of malignant change, we did not have any metastases. Since then, two of these cases have developed intrathoracic malignant tumors, which I am inclined to believe are metastatic lesions. In both cases, these have become clinically apparent three years following local excision of a histologically proved giant-cell tumor.

DR. C. LESLIE MITCHELL, Detroit, Michigan: I was very much interested in Dr. Hatcher's paper because I had reached the same conclusions. A few years ago, a young girl, fourteen years of age, reported to the Clinic with a lesion of the lower end of the tibia, which on biopsy proved to be a giant-cell tumor. She was given deep x-ray therapy, and about a year and a half later a lesion of the malleolar portion of the fibula developed. Biopsy showed fibrosarcoma, and amputation was carried out. Subsequently, metastatic nodes in the inguinal region were excised. There has been no recurrence after seven years.

Subsequently we have had two other cases, similar in many respects, with malignant degeneration of a benign lesion following deep x-ray therapy. One of these cases was a giant-cell tumor of the tibia, treated by Dr. Peabody ten years ago by deep x-ray therapy. The other one was a benign cyst of the humerus in a young girl, with development of sarcoma six months following irradiation.

DR. C. HOWARD HATCHER, Chicago, Illinois (closing): The cases reported by Dr. Ransohoff and by Dr. Mitchell are interesting ones and important, because of their rarity in American literature. It is possible that some benign giant-cell tumors which have been reported to undergo malignant change are examples of sarcoma induced by therapeutic irradiation.

It should be emphasized that the cases of irradiation sarcoma reviewed in this paper occurred mostly during a period when x-ray therapy was not so well controlled as to indications and dosage as it is now.

How irradiation acts in producing malignant change in bone is unknown. We do know that bony tissue undergoes avascular necrosis following intensive irradiation, and its repair is very slow. It is probable that neoplasia occurs in either the marrow elements, or in the scar tissue which repairs the region damaged by irradiation.

AN EVALUATION OF THE ESTIMATED PERCENTAGE OF GROWTH FROM THE DISTAL EPIPHYSEAL LINE

BY IRVIN E. HENDRYSON, M.D., PHILADELPHIA, PENNSYLVANIA

From the University of Pennsylvania, Graduate School of Medicine

The difficulty of estimating the expected growth of a long bone is stressed more and more by the increased interest in the problem of equalization of length of the lower extremities, particularly in considering the operation of epiphyseodesis. Digby measured a set of long bones, and established a standard scale of growth from distal and proximal epiphyseal lines. Bisgard and Bisgard substantiated his findings by experimentation with animals. Wilson and Thompson then applied the same figures clinically in an effort to determine the expected growth in an extremity. By estimating the percentage of growth from each epiphyseal line, they corrected the discrepancy by epiphyseodesis, as outlined by Phemister.

In explaining the basic principle involved, Digby postulated that:

". . . the nutrient canal always points toward the oldest part of the shaft of the long bone. It is more accurate to say that the canal points towards *the site which the oldest part of the bone would occupy were it not that the osseous tissue first formed is subsequently absorbed in providing the medullary cavity.* . . . The initial point of ossification may be easily determined, for it corresponds to that point in the centre of the medullary cavity which is reached by an imaginary prolongation of the nutrient canal. The site of initial ossification having been determined, it becomes easy to measure the precise lengths of bone which are formed from the two growing ends of the diaphysis. . . .

". . . and also in the case of the adult femur where, when two foramina are present (as not infrequently happens), the nutrient canals have different obliquities, so that when prolonged they converge on almost the same point in the medullary cavity."

Following this principle, Digby measured a set of long bones and established percentages of growth from distal and proximal epiphyseal lines which are now used (Table I).

The present study was undertaken primarily to evaluate this method of estimating growth. An attempt was also made to arrive at a standard mean of growth in a large series of cases, rather than to accept figures derived from one isolated set of measurements.

METHOD

1. *Material.* Measurements were made on fifty-four adult, human femora, selected at random from dried anatomical laboratory specimens. Of this number, forty-eight had a single nutrient canal, while six were discovered to possess two such canals. Because of this variation, they were considered separately, forming Group A and Group B in this report. Two femora from the new-born were secured and identical studies made on them; these form Group C.

TABLE I

A Comparison of Digby's Scale with Specimens Showing Extremes in Length and Percentage Growths from the Distal Epiphyseal Line of the Femur

Specimen Number	Diaphyseal Length (*Centimeters*)	Growth from Distal Epiphysis (*Centimeters*)	(*Per cent.*)
103	45.5	32	70
94	34	24	70.5
14	43.5	34.5	79
24	37	18.5	50
Digby's Scale:	16 inches (40 centimeters)	11 inches (27.5 centimeters)	69 per cent.

2. *Mensuration.* In making the measurements of the femora it was decided that more exact data could be secured by making roentgenograms of the bones and measuring them. This procedure was carried out by first passing a small needle along the nutrient canal into the medullary cavity, and fixing it with modeling clay. The entire femur was then mounted on a cassette with clay so that roentgenograms could be made. In each case it was fixed so that the rays would pass to the canal at a right angle.

Regular, ultra-speed film was used in making the roentgenograms. Exposures were made at seventy-two inches, with seventy-five peak kilovolts, twenty milliamperes, for fifteen seconds.

In determining the location of the metaphysis it was noted that after closure of the epiphysis a suitable variation in density did not always appear to reveal the site of closure. Two specimens in the group revealed epiphyseal lines which were nearly obliterated. From these, points were found which were present in all of the specimens, and which showed definitely the plane where metaphysis and epiphysis fused.

It then became possible to measure the over-all length of the shaft and the distance between Digby's "site of initial ossification" and the distal and proximal ends of the shaft.

EXPERIMENTAL DATA

Group A

Forty-eight specimens were measured. The maximum length of diaphysis encountered was 45.5 centimeters (Specimen 103), and the minimum length was 34 centimeters (Specimen 94). The maximum growth from a distal epiphyseal line was 34.5 centimeters (Specimen 14), and the minimum growth from a similar structure was 18.5 centimeters (Specimen 24). The length of the shaft in the former (Specimen 14) was 43.5 centimeters, and in the latter (Specimen 24) 37 centimeters. As a result, the greatest individual growth from a distal epiphyseal line was 79 per cent., while the smallest percentage of growth was 50 per cent. (Table I). The remaining bones exhibited growth percentages which fell between these extremes.

After the percentage growth from the distal epiphyseal line in each femur had been established, a percentage growth mean for the series could be computed. This figure was 71 per cent. Yet it gave no indication of the variation from the mean. This latter figure is known as the Standard Deviation and is derived from the formula:

$$S\,D = \sqrt{\frac{Sum\ of\ the\ squares\ of\ the\ observations}{Number\ of\ observations} - (Mean\ of\ the\ observation)^2}$$

In this series the Standard Deviation from the mean was ± 6.5 per cent. Therefore, the average percentage of growth to be expected from the distal epiphyseal line in a femur would be in the range between 64.5 per cent. and 77.5 per cent.

Group B

This group was composed of six femora exhibiting dual arterial supply. The method was the same as that used in Group A except that a needle was inserted into each arterial canal before the plates were made.

A study of these films revealed that in four of the femora the expected intersection of the prolonged nutrient canals did not occur. Table II reveals the diaphyseal length in these bones and the distance from the distal metaphysis to each medullo-nutrient canal intersection.

In the remaining two femora the arteries intersected. The measurements obtained and the resulting proposed percentage of growth from the distal epiphyses are shown in Table III.

TABLE II

MEASUREMENTS IN WHICH ARTERIAL PROLONGATIONS DID NOT INTERSECT

Specimen Number	Diaphyseal Length (*Centimeters*)	Length from Distal Artery (*Centimeters*)	Length from Proximal Artery (*Centimeters*)
101	38.5	34	29
98	40.5	34.5	29.5
97	39	31	25
108	42.5	32	25.5

TABLE III

MEASUREMENTS IN FEMORA WHOSE ARTERIAL PROLONGATIONS INTERSECTED

Specimen Number	Diaphyseal Length (*Centimeters*)	Growth from Distal Epiphyseal Line (*Centimeters*)	(*Per cent.*)
107	38.5	28.5	75
99	43	31.5	73

Group C

Two new-born infant femora composed this group. One of these possessed a single nutrient artery. The other was found to have a dual arterial supply.

Measurement of the first revealed the distance from the metaphysis to the medullonutrient artery point to be 6.5 centimeters. In the second case the prolongation of the nutrient arterial canals did not intersect in the medullary cavity. As a result, measurements were deemed unnecessary.

DISCUSSION

From the most casual evaluation of the above data it would seem obvious that the original premise is without foundation. Two facts seem evident: first, considering the method of measurement as postulated by Digby to be sound, there is too much variation around the mean, in a large series of cases, to warrant the use of an estimated percentage of growth from a given epiphyseal line; second, the assumption that two nutrient arteries intersect in the medullary cavity at a point indicating the oldest part of the bone is false. This is clearly demonstrated by four of six adult femora which possessed dual arterial supply; and is further substantiated by the fact that at birth these arteries do not of necessity intersect. Because of this, it is felt that the method outlined for estimating percentage of growth from a given epiphyseal line is unsound and the figures are unreliable.

CONCLUSION

1. The established method, or Digby's method, of determining percentage of growth from a given epiphyseal line in a long bone (by comparing the diaphyseal length with the distance from the metaphysis to the intersection of the nutrient artery and the center of the medullary cavity) is unreliable and without foundation.

2. The figures derived by the use of this method in estimating the percentage of growth from a given epiphyseal line are inaccurate.

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ADHESIVE CAPSULITIS OF THE SHOULDER

A Study of the Pathological Findings in Periarthritis of the Shoulder *

BY JULIUS S. NEVIASER, M.D., WASHINGTON, D. C.

Periarthritis of the shoulder has long been familiar to orthopaedic surgeons. Other names applied to this condition are "frozen shoulder", "stiff and painful shoulder", "periarticular adhesions", "tendinitis of the short rotators", "adherent subacromial bursitis", "scapulohumeral periarthritis", and "Duplay's disease". The clinical picture is characterized by pain and limitation of motion in abduction, and in both internal and external rotation.

The consensus of opinion of most of the many writers on the subject may be summed up in a few pertinent statements. The condition is regarded as a separate clinical entity. Little is known of its pathology, and exposure of the bursa in a few instances has revealed no consistent abnormality. Motion was restored only after adhesions had been overcome. The adhesions were probably in the substance of the tendinocapsular structures.

This study was undertaken with the hope that through surgical exploration of the shoulder joint some light could be thrown on the pathology of this condition. In ten such cases, the operative findings were noted, and some were recorded in motion pictures as well. In addition, sixty-three shoulders of thirty-six persons who died from various causes were exposed at autopsy, and specimens were taken for microscopic study.

With one exception, upon roentgenographic examination, the patients selected for operation showed no changes in and about the shoulder joint. The exception (Case 7) revealed a calcification in the short rotator cuff. All patients had pain with limitation of motion in abduction and in both internal and external rotation. Forward flexion and backward extension were painless and not limited. After the operation on the first patient, oxygen was injected into both shoulder joints of the three subsequent cases, under local anaesthesia. This was done in an effort to determine whether or not oxygen would distend the capsule and show an air space around the head of the humerus in the normal shoulder. It was felt that an adherent capsule in the abnormal shoulder would prevent the entrance of much oxygen and thus would not reveal a distended capsule. (However, the tests were equivocal and without clinical value, and were subsequently omitted.) The affected shoulders of these three patients were then explored by operation as in the other seven cases.

At this point it might be well to review the anatomy of the normal shoulder joint. The articular capsule completely envelops the joint. It is remarkably loose, and this accounts for much of the free movement of this joint in all directions. The capsule is prolonged downward in the form of a fold in the ordinary dependent position of the arm (Fig. 1). When the arm is abducted, this fold becomes obliterated and the capsule tense. Synovial membrane lines the fibrous layer of the capsule. It extends from the margins of the glenoid cavity over the inner surface of the capsule, and covers the lower part and sides of the anatomical neck of the humerus, where it is reflected toward the margin of the articular cartilage of the humeral head. It is important to remember that the inferior aspect of the humeral neck has the most extensive clothing of synovial membrane (Figs. 1 and 2). On all aspects, except the inferior, the capsular ligament is supported by muscles, the tendons of which are more or less intimately connected with it. This intimate union of the tendons of the supraspinatus, infraspinatus, teres minor, and subscapularis muscles converts them into supporting ligaments of the joint. The entire enveloping structure is generally called the capsulotendinous or musculotendinous cuff of the shoulder.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1944.

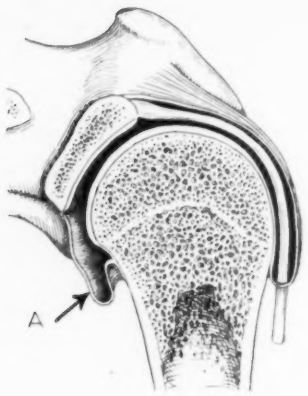

FIG. 1

A vertical section through the shoulder joint, showing (*A*) the fold of capsule of the joint with the synovial membrane lining its inner surface.

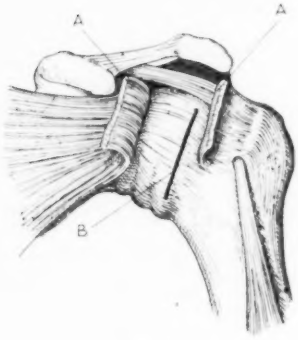

FIG. 2

Capsule of shoulder joint, exposed by section of (*A*) tendon of subscapularis. *B* indicates line of incision in the capsule.

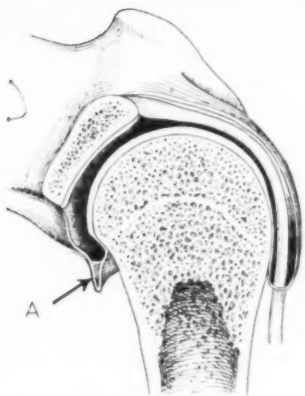

FIG. 3

A vertical section through the shoulder joint, showing the adhesion of (*A*) the reflected dependent part of the capsule.

However, in this paper, when reference is made to the term capsule, it signifies the true articular structure, particularly the synovial lining and subsynovial tissue.

The incision used for the exploratory arthrotomy was about ten centimeters long, following the line of separation between the deltoid and pectoralis major muscles. The cephalic vein was retracted in a lateral direction, and the muscle fibers were separated by blunt dissection. The subacromial bursa showed no gross pathological changes. The coracobrachialis and short head of the biceps were retracted strongly in a medial direction. The fibers of the subscapularis were separated from the capsule close to their insertion by means of a pointed elevator, and then divided by a vertical incision approximately 2.5 centimeters long. This gave a satisfactory exposure of the anterior portion of the capsule. This was divided by an oblique incision about 1.25 centimeters from the attachment of the capsule to the anatomical neck (Fig. 2). Its length varied somewhat in the series; the average was 3.75 centimeters.

An incision in the capsule, placed in this manner, normally opens into the joint with a consequent escape of synovial fluid. In all of the frozen shoulders, however, there was a conspicuous absence of synovial fluid and the redundant capsule, instead of showing the normal separation from the humeral head, was adherent to it. By means of a suitable elevator, the capsule could easily be separated from the cartilage. No bleeding could be detected during this procedure, thus indicating that the adhesion was not due to vascular bands. This adhesion was similar to that of adhesive plaster applied to the bare skin. The capsule could also be separated from the head by rotating the arm; in fact this was the method used in most of these cases. During manipulation, the head and the capsule, at first seemingly glued together, were separated after one or two rotational movements. Free rotation was then possible. It was evident that the capsule had been under tension, because the two cut edges retracted, leaving a gap of about two centimeters. The capsule was thicker than normal, as observed in cadaver experiments and in operations for recurrent dislocations. At the reflection of the capsule near the anatomical neck, a tearing apart of the adhesions binding the fold of the capsule was seen distinctly. During the abduction manoeuvre, it was possible to observe a space between the capsule and the humeral head.

In most instances, after manipulation, the margins of the divided capsule retracted so much that they could not be sutured together without a great deal of tension. Therefore, in closing, the capsular wound was never sutured. The patient was treated postopera-

tively in the same manner as if a closed manipulation had been done. It should be emphasized that this operative procedure is not offered as a treatment. It is merely described in detail to bring out the gross pathological findings. At operation, sections were taken from the bursa, capsule, and humeral head for microscopic study.

The shoulders of ten patients suffering from "frozen shoulder" or "periarthritis of the shoulder" were explored at operation. Cultures taken from these joints were negative. In nine cases, the capsule was contracted and closely adherent to the humeral head at its anterior inferior portion. Adhesions were discernible at the reflected fold of capsule distal to the anatomical neck (Fig. 3). In Case 8, the capsule did not snap free during the manipulation, as was true in the other nine cases, although initial inspection anteriorly revealed it to be tense. After manipulation, however, the capsule could be picked up loosely from the articular cartilage. The cause of this difference could not be visualized through our operative incision. In Case 10, a tenosynovitis of the long head of the biceps tendon was observed.

The sections of bursa and capsule taken from these shoulders revealed microscopic changes in either or both. Removal of sections of articular cartilage was discontinued, after four had shown a picture consistent with the usual degenerative changes from wear and tear.

CASE STUDIES

CASE 1. P. F., colored female, fifty-six years old, came to the orthopaedic clinic at The Emergency Hospital complaining of pain in the left shoulder of two months' duration. There was no history of injury. Pain was severe when attempts were made to use or to exercise the left arm, and became worse at night. Roentgenograms were negative. Shoulder motion was restricted in abduction, and in internal and external rotation. An arthrotomy of the left shoulder was performed on February 8, 1940. At operation, the capsule appeared to be hypertrophied and contracted over the head of the humerus. During manipulation of the arm, the capsule gradually became separated from the humeral head.

Microscopic Findings:

Bursa: Beginning hyalinization of the synovial villi was apparent. There was also fibrosis and cellular infiltration by mononuclear leukocytes of the bursal wall. There was vascular dilatation of the blood vessels.

Capsule: Synovial cells revealed no change. There was a fairly extensive fibrosis and chronic inflammation of the subsynovia manifested by infiltration of mononuclear leukocytes. Some perivascular infiltration was noted.

CASE 2. I. D., white male, sixty-three years old, came to the orthopaedic clinic at The George Washington University Hospital, complaining of pain in the left shoulder of about three months' duration. Pain had gradually increased, until the patient could not raise his arm or place his left hand behind him. The only history of injury was a fractured left arm suffered at the age of two years. Roentgenograms were negative. All motions were restricted, except forward and backward flexion. Oxygen injection, as described before, gave no information. An arthrotomy of the left shoulder was performed on April 26, 1941. The capsule, which was contracted and firmly adherent to the anterior inferior portion of the humeral head, peeled away when the arm was manipulated.

Microscopic Findings:

Bursa: Vascular dilatation with a slight degree of fibrosis of the synovial lining was noted. The hyalinization of some of the villous folds (Fig. 4) suggested the possibility of a pre-existing bursitis.

Capsule: The synovial cells were normal. There was vascular dilatation in the subsynovia.

Cartilage: Normal.

CASE 3. S. P., white male, fifty-six years old, was seen in the orthopaedic clinic at The Emergency Hospital, complaining of pain in the right shoulder of three months' duration. He described the pain as a dull ache, especially upon movement of the arm. Thirty-six years before, he had broken his right forearm, but had had no trouble from this injury. Roentgenograms were negative. There was definite limitation of motion in abduction and in external rotation, and internal rotation was also restricted. Oxygen injection was of no value. At operation on April 28, 1941, a thickened and adherent capsule was found. Upon manipulation, the capsule snapped off the humeral head, allowing complete freedom of motion. This case illustrated the contracture of the capsule and the adhesions so well that the decision was made to take motion pictures of subsequent cases.

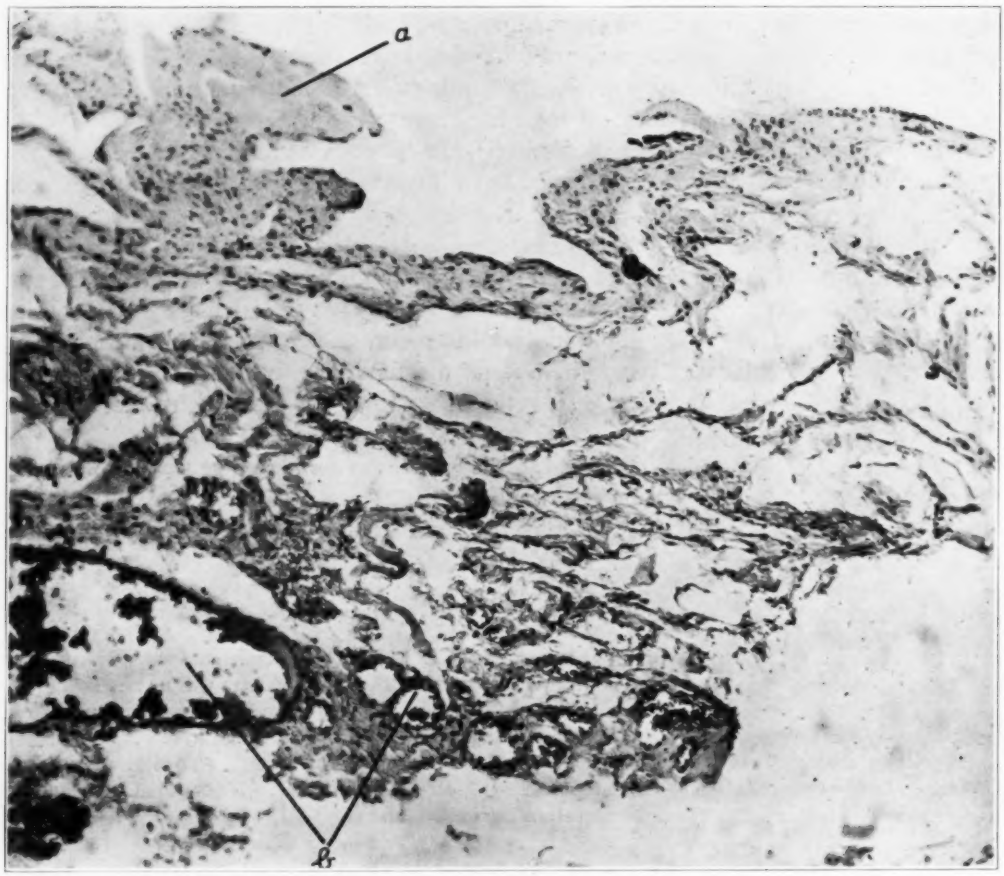

FIG. 4

Case 2. Photomicrograph (×100) shows (*a*) hyalinization of some of the villous folds and (*b*) vascular dilatation of the bursa.

Microscopic Findings:

Bursa: The bursa was inflamed. Attached directly to the synovial surface was a veil-like mass of fibrin in the meshes of which were moderate numbers of mononuclear leukocytes (Fig. 5-A). There was proliferation of the synovial cells. Perivascular round-cell infiltration of the blood vessels was noted. It was decided that chronic bursitis was probably responsible for the patient's condition.

Capsule: Here too was a definite inflammatory response. There was a moderate degree of perivascular infiltration with lymphocytes. Cystic degeneration or oedema was noted in the subsynovia (Fig. 5-B). There was no synovial lining in the section.

Cartilage: Cystic degeneration.

CASE 4. M. O., white female, fifty-eight years old, was seen at the orthopaedic clinic of The George Washington University Hospital, complaining of pain in the right shoulder. Eight months previously she had had a severe infection in the index finger of the right hand, which had cleared up after several weeks of treatment. The patient was a diabetic. Four months later she had begun to have pain on motion in the right shoulder, which became progressively worse. Three weeks before examination, the pain had become quite severe, and she had started to have definite limitation of motion. Roentgenograms were negative. Oxygen injection was valueless. Motions were definitely limited in abduction, and in external and internal rotation. An arthrotomy was performed on June 30, 1941. A thickened and adherent capsule was found. During the manipulation, the capsule peeled away from the humeral head. Motion pictures were made of this case.

Microscopic Findings:

Bursa: Showed a slight increase in the blood vessels in the synovia.

Capsule: There was no synovial lining in the section. There was a moderate fibrosis of the subsynovia, a slight degeneration of the collagen, and a focal area of calcification (Fig. 6).

Cartilage: There was considerable fibrillation of the hyaline cartilage indicating degeneration.

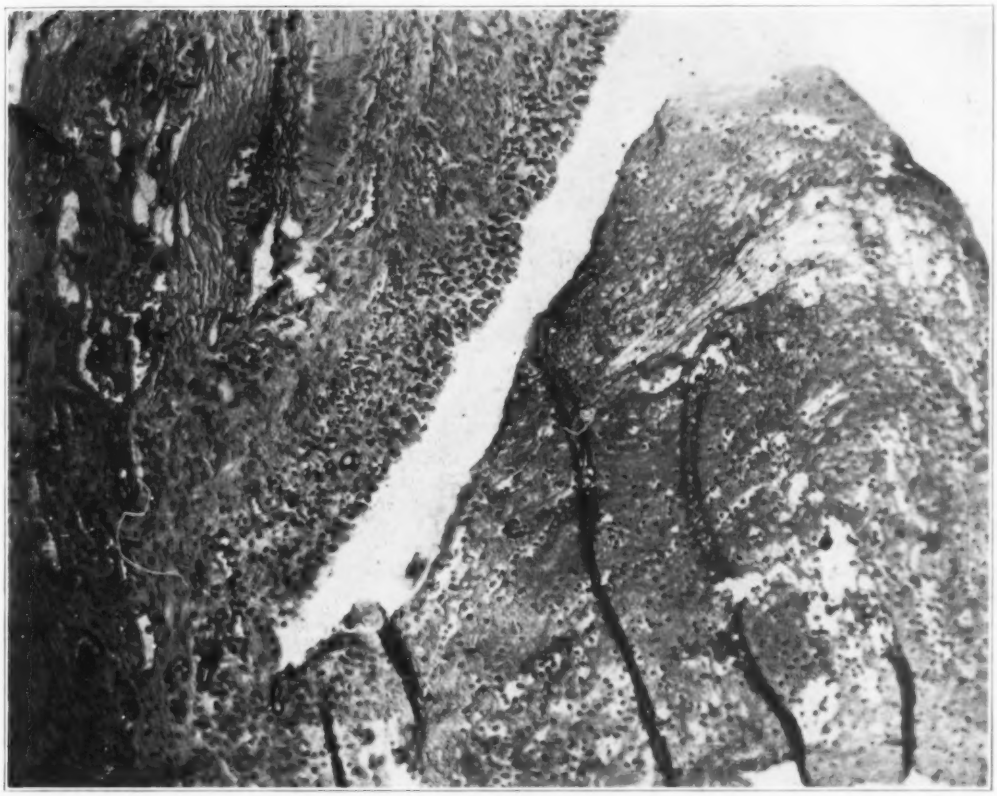

FIG. 5-A

Case 3. Photomicrograph (×100) shows (*a*) proliferation of the synovial cells of the bursa. Attached directly to the synovial surface (*b*) there is a veil-like mass of fibrin in the meshes of which are moderate numbers of (*c*) mononuclear leukocytes.

FIG. 5-B

Case 3. Photomicrograph (×80) shows (*a*) oedema in the subsynovia of the capsule and (*b*) perivascular cuffing.

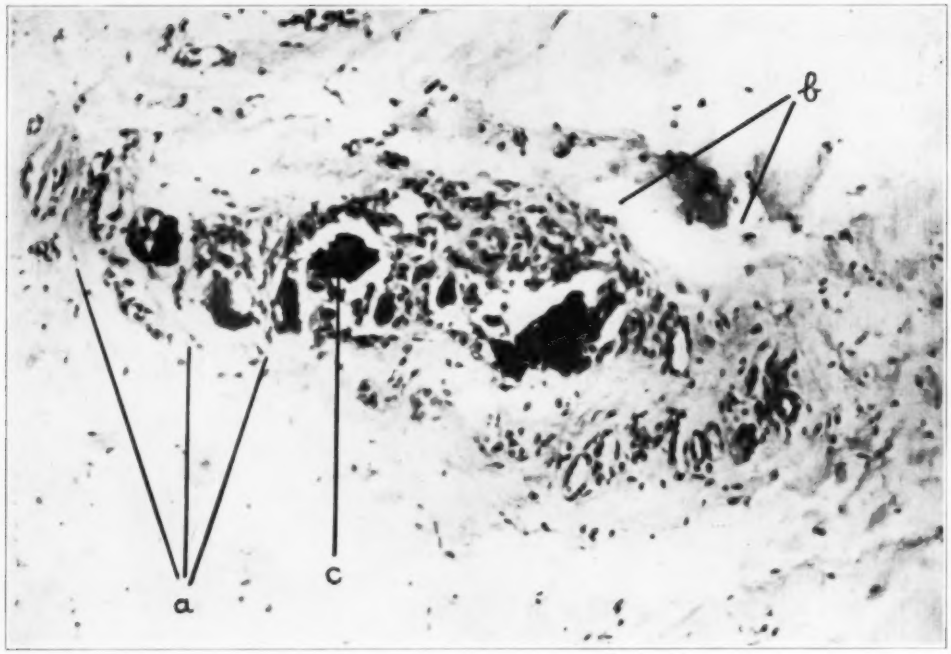

FIG. 6

Case 4. Photomicrograph (×80) of capsule showing (*a*) fibrosis of subsynovia, (*b*) slight degeneration of collagen, and (*c*) a focal area of calcification.

CASE 5. L. L., white male, sixty-one years old, seen at the orthopaedic clinic of The George Washington University Hospital, complained of pain in the left shoulder of six months' duration. Onset of pain in both shoulders was gradual, but after two weeks, pain disappeared in the right shoulder and persisted in the left shoulder. Pain had been worse during the last two weeks. Roentgenograms revealed no changes in the shoulder joint. Although abduction and external rotation were limited, internal rotation was particularly restricted. Operation was performed on May 7, 1942. During the manipulation, the capsule quickly separated away from the head of the humerus with a tearing apart of the synovial folds. Findings were recorded by kodachromes.

Microscopic Findings:

Bursa: There was slight proliferation of synovial cells, and fibrosis and chronic inflammation in the subsynovia.

Capsule: There was a slight proliferation of the lining synovial cells of the capsule, as well as a few scattered cells, mostly lymphocytes, about the vessels in the subsynovia.

Cartilage: There was a slight degree of degeneration of the hyaline cartilage.

CASE 6. M. S., white female, forty-six years old, complained of pain in the left shoulder and inability to use her left arm freely. Pain had been present for five months, and had become so severe that the patient had to walk the floor at night. She had undergone chiropractic treatments without relief. There was the usual restriction of motion, with abduction of 45 degrees, and she was unable to touch the left buttock with her left hand. Roentgenograms were negative. Motion pictures were taken of the operation on June 15, 1942. The thickened contracted capsule quickly peeled off the articular cartilage during the manipulation.

Microscopic Findings:

Bursa: There were a few lymphocytes in the wall of the bursa, and a slight proliferation of the synovial cells.

Capsule: The synovial capsule was essentially normal.

CASE 7. D. D., white female, thirty-three years old, complained of pain in the right shoulder of five years' duration. She had been told that she had a calcified subdeltoid bursa. She had had episodes of pain during that time, and had been treated by diathermy, x-ray, and aspiration with temporary relief. She was seen by Commander Robert Mazet on May 5, 1942, who noted pain but a good range of motion. Roentgenograms taken on May 8 revealed a large calcified bursa in the right shoulder. When seen again on July 6, she had extreme pain and practically no range of motion except forward and backward flexion. The operation

was performed on July 10, 1942, by Captain Hook and Commander Mazet (this case was presented through their courtesy). After the subdeltoid bursa had been exposed and the calcified material allowed to escape, the shoulder still remained restricted in motion. After the incised adherent capsule had been manipulated, it suddenly snapped away from the head of the humerus, allowing it to become free, with full range of motion in the shoulder.

Microscopic Findings:

Bursa: There was a moderate amount of fibrosis and chronic inflammation of the bursal wall, characterized by the presence of mononuclear leukocytes.

Capsule: There was one small area of calcification in the subsynovia. There was no synovial lining in the section.

Case 8. F. K., white male, fifty-two years old, examined for pain in the left shoulder of six months' duration. He attributed the trouble to "exposure to draft". Pain had been worse in the last month, and he could not use the arm freely. There was no history of injury. He had not received treatment. Active abduction was limited to 60 degrees. Internal and external rotation were also limited. Roentgenograms revealed no changes in the left shoulder. The shoulder was exposed on August 24, 1942. In this instance, the adherent capsule did not snap free or peel off the humeral head during the manipulation, but after this procedure it became loose and could be easily raised from the articular cartilage by a forceps. It is believed that the adhesions in this case were probably so situated that it was impossible for the surgeon to visualize them.

Microscopic Findings:

Bursa: The bursa showed no alteration of importance.

Capsule: There was no synovial lining in the section. There was considerable fibrosis and degeneration of the collagen of the subsynovia (Fig. 7).

Case 9. D. C., white female, was forty-seven years old. Three months before the examination, the patient had had trouble with her left arm, with a gradual onset of slight pain in the shoulder, which became quite severe at night. Active abduction was limited to 70 degrees. External rotation was more restricted than internal rotation. Roentgenograms revealed no evidence of any bone or joint changes in the left shoulder. An arthrotomy was performed on the left shoulder on October 19, 1942. During manipulation of the shoulder, the contracted capsule peeled off the head of the humerus, allowing the arm complete range of motion.

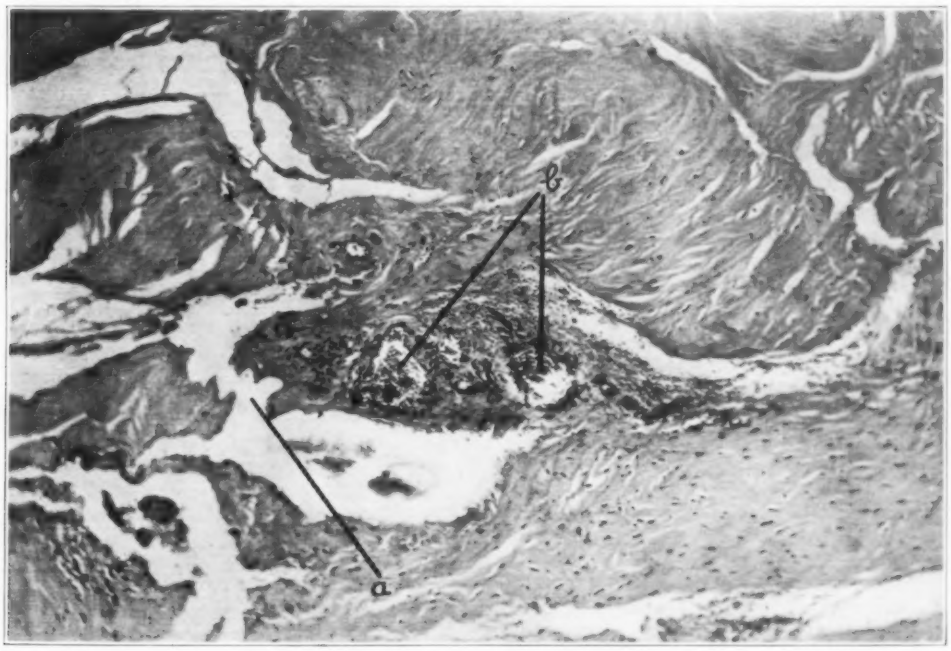

Fig. 7

Case 8. Photomicrograph (×80) of capsule shows (*a*) degeneration of collagen of the subsynovia and (*b*) vascular dilatation and perivascular infiltration.

Microscopic Findings:

Bursa: There was no evident change in the bursa.

Capsule: There was moderate fibrosis and considerable perivascular lymphocytic infiltration (Figs. 8-A and 8-B).

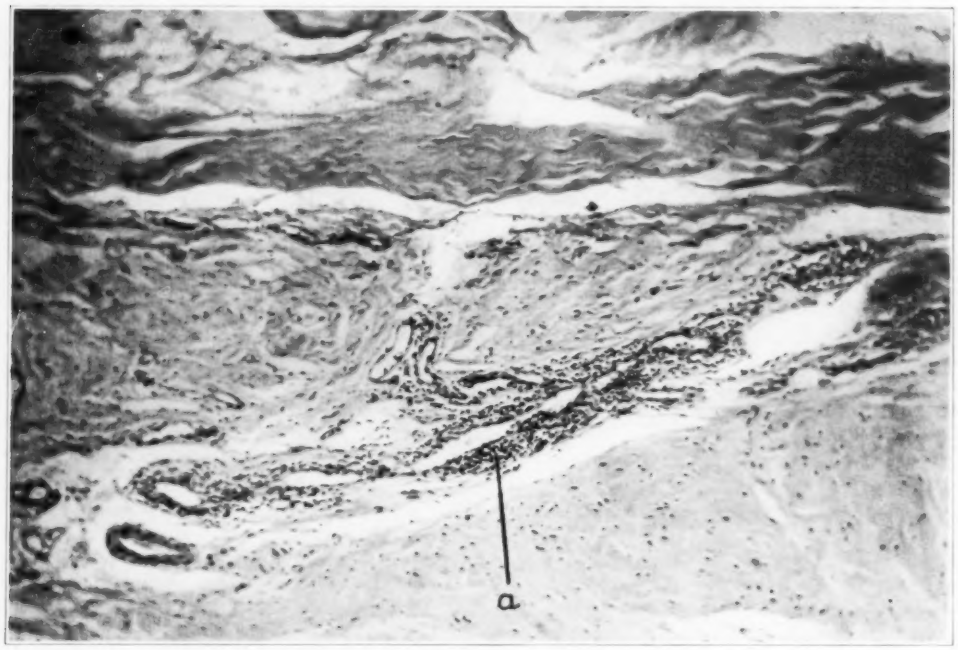

FIG. 8-A

Case 9. Photomicrograph (×80) shows (*a*) perivascular lymphocytic infiltration in the capsule.

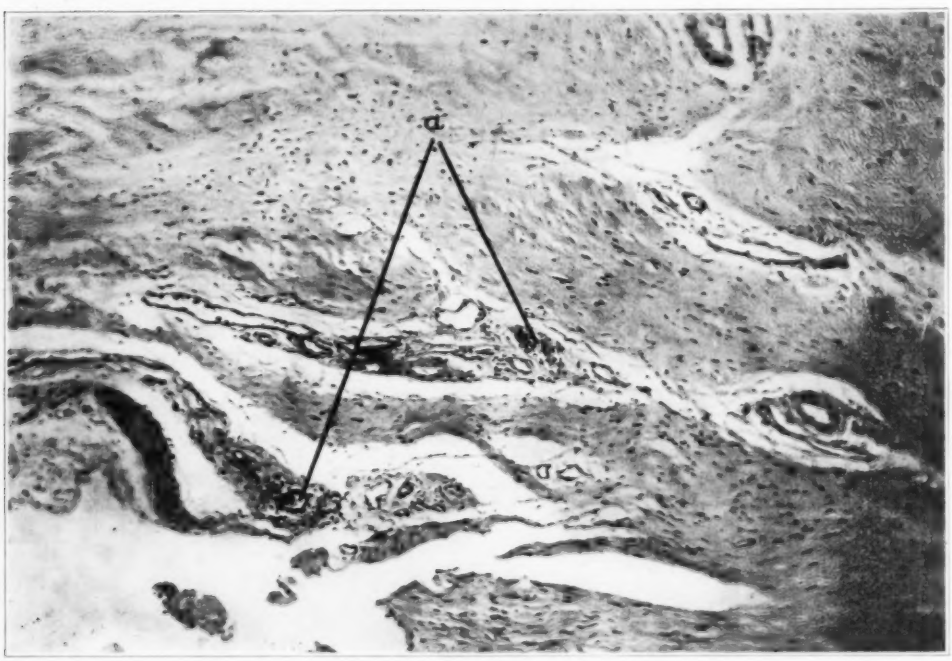

FIG. 8-B

Case 9. Photomicrograph (×80) of another section of capsule showing (*a*) perivascular lymphocytic infiltration.

CASE 10. D. L., white male, forty-five years old, had fallen from a ladder injuring his left shoulder seven weeks before admission. Roentgenograms were negative. He had been treated by diathermy and ordered to rest. His arm was in a sling for about two weeks. With active motion, the arm pained him so that it kept him awake at night. Active abduction was 90 degrees. External rotation was limited to about 30 degrees. Internal rotation was restricted so that the left hand touched back just above the belt line. Forward flexion and backward extension were good. Operation was performed on the left shoulder on August 9, 1943. A tenosynovitis of the long head of the biceps tendon was observed. The incision showed the capsule so contracted and tightly adherent to the humeral head that it was difficult to insert a flat instrument between it and the head of the humerus. After manipulation, when the capsule snapped free and the synovial folds tore apart, this was easily accomplished.

Microscopic Findings:

Bursa: No abnormal changes were noted.

Capsule: Chronic inflammatory changes were manifested by infiltration of mononuclear leukocytes, and the presence of granulation tissue. There was absence of synovial cells.

SUMMARY

Bursa: There were varying degrees of inflammation of the bursa in seven of the ten cases examined.

Capsule: The synovial lining in the ten cases examined (Table 1) did not present a continuous layer of cells in all sections. In four instances the cells which were present

TABLE I

PATHOLOGICAL DESCRIPTION OF TISSUES TAKEN FROM PATIENTS WITH "FROZEN SHOULDERS"

Case	Synovia (Capsule)			Bursa			Cartilage
	Synovial Cells	Subsynovia	Blood Vessels	Synovia	Subsynovia	Blood Vessels	
Case 1 P. F.	Negative	Fibrosis and chronic inflammation	Perivascular infiltration	Beginning hyalinization of villi	Fibrosis and chronic inflammation	Vascular dilatation	
Case 2 I. D.	Negative	Vascular dilatation	Altered to simulate granulation tissue	Fibrinoid necrosis	Negative	Increase in thin-walled blood vessels.	Negative
Case 3 S. P.	——	Cystic degeneration	Perivascular infiltration	Proliferation and fibrin	Extensive inflammation	Perivascular round-cell infiltration	Cystic degeneration
Case 4 M. O.	——	Calcification. Fibrosis. Degeneration of collagen	Slight perivascular infiltration	Slight increase in blood vessels	Negative	Negative	Fibrillation
Case 5 L. L.	Slight proliferation	Negative	Perivascular infiltration	Slight proliferation	Fibrosis and chronic inflammation	Negative	Slight degeneration
Case 6 M. S.	Negative	Negative	Negative	Slight proliferation	A few lymphocytes	Negative	
Case 7 D. D.	——	Calcification	Negative	Negative	Fibrosis and chronic inflammation	Negative	
Case 8 F. K.	——	Fibrosis and degeneration of collagen	Dilatation and perivascular infiltration	Negative	Negative	Negative	
Case 9 D. C.	Negative	Fibrosis	Perivascular infiltration	Negative	Negative	Negative	
Case 10 D. L.	——	Chronic inflammation	Altered to form granulation tissue	Negative	Negative	Negative	

NOTE: —— indicates absence of synovial cells.

TABLE II

ANALYSIS OF AUTOPSY CASES WHICH REVEALED ADHERENT CAPSULES

Case and Number	
C. K. 57789	Both shoulder capsules were contracted when removed. They were firmly adherent to the articular cartilage. The reflected folds were adherent. Microscopic changes consisting of fibrinoid necrosis and lymphocytic infiltration were seen only in left capsule.
C. M. 57800	Nothing was found either on gross or microscopic examination of right shoulder capsule. In left shoulder a large adhesive band was found anteriorly close to the anatomical neck. Fibrosis was noted in subsynovial layer.
C. B. ——	Right shoulder capsule was adherent. Slight proliferation of synovial cells and fibrosis was noted in subsynovial layer.
C. E. 57829	Both capsules were contracted and adherent to the humeral head. Proliferation of synovial cells was noted.
L. P. 57835	Capsules were quite adherent throughout in both shoulders. Reflected folds were slightly adherent. No microscopic changes were noted in right capsule, but inflammation was observed in left capsule.
C. S. 57671	Both capsules were contracted and firmly adherent over articular cartilage and difficult to remove. Patient had chronic arthritis but gave no history of shoulder pains. No gross arthritic changes were noted in the shoulder joint. Fibrosis and degeneration of collagen were noted in both capsules.

appeared normal; in one instance they showed evidences of proliferation; and in the five remaining cases no synovial cells were found. In these five cases it is probable that the synovial cells, which were originally present, had been destroyed in the formative stages of the process or during manipulation at the time of operation.

In the subsynovial layer there was fibrosis and degeneration of the collagen in two instances, calcification in two, and chronic inflammation characterized by fibrosis and perivascular infiltration in six instances.

The blood vessels were essentially normal.

Elastic-tissue stains were also made of all sections, but they did not reveal any significant change in the collagen.

Hyaline Cartilage: There was a moderate amount of degeneration in three or four cases examined. These changes might well be within normal limits.

In all ten cases there were changes demonstrated in either the capsule or the bursa or both. The microscopic sections revealed a nearly consistent pathological picture of reparative inflammatory changes, which consisted of degeneration, vascular repair, cuffing of the blood vessels, and mononuclear cells to a lesser or greater degree.

DISCUSSION OF THE AUTOPSY CASES

The synovial capsules from both shoulder joints of twenty-seven patients who had died from various causes, and one shoulder from nine additional patients, were examined, making a total of sixty-three shoulders. The youngest were stillbirths and the eldest was eighty-seven years of age, the average age being forty-four and six-tenths years. There were no demonstrable differences between the right and the left side. Elastic-tissue stains were of no value.

There was fibrosis of the subsynovia, calcification, focal degeneration of the collagen, or a slight amount of chronic inflammation in fourteen of sixty-three shoulders (22.2 per cent.). It is of interest to note (Table II) that in eight of the fourteen shoulders which showed microscopic changes, the capsule was contracted and closely adherent to the humeral head. This would leave only six shoulders (9.5 per cent.) which showed microscopic changes in the capsule, but revealed no gross changes.

One of the six remaining shoulders (J. M., No. 57391) showed an acute inflammatory process, characterized by an infiltration of polymorphonuclear leukocytes in addition to a more diffuse chronic process, consisting of an infiltration of small mononuclear leukocytes distributed chiefly around blood vessels. This acute inflammatory reaction is not part of the pathological entity which forms the basis of this paper. Interestingly enough, the capsule was not contracted or adherent at the time of its removal.

CONCLUSIONS

This study of "frozen shoulder" was undertaken to clarify the pathology, and is not offered as a method of treatment. The results demonstrate that the lesion is not a periarthritis, but the essential pathology is a thickening and contraction of the capsule which becomes adherent to the humeral head. Microscopic sections confirm the presence of reparative inflammatory changes in the capsule. In some cases, there are also similar changes in the wall of the subacromial bursa. During manipulation of a "frozen shoulder" under anaesthesia, the capsule is separated from the head in much the same way that adhesive plaster can be torn away from the bare skin. Once this separation has occurred, motion of the head within the joint is free.

The term "adhesive capsulitis" is suggested as descriptive of the pathology of "frozen shoulder".

NOTE: The author is greatly indebted to Colonel J. E. Ash, Lieutenant Colonel D. Murray Angevine, and Major Alfred Golden of the Army Medical Museum for their kind cooperation, their complete review of the pathological material, and their many helpful suggestions.

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RESULTS OF MODERN METHODS OF TREATMENT OF POLIOMYELITIS *

BY ROBERT W. JOHNSON, JR., M.D., BALTIMORE, MARYLAND

A reappraisal and a report of our successful, although unspectacular, treatment of poliomyelitis patients at the Children's Hospital School, and elsewhere in Baltimore, may prove helpful and enlightening to orthopaedic surgeons in other sections. The accurate and consistent records which we are fortunate in having make such a report possible. At the 1942 meeting of the Association in Baltimore, Dr. Raymond Lenhard [1] presented in considerable detail the complete figures on the cases treated between 1932 and 1938. The figures presented herewith include only the cases from the 1941 epidemic.

Our figures are presented for exactly what I think they are worth—interesting information—and I wish to state frankly that while I think our results are encouraging and satisfactory, they cannot be regarded as a primary justification of our regimen. I have confidence in our treatment because it is based on the sound foundation of the accredited pathology of the disease, and a reasonable conception of the pathological physiology of denervated muscle, its maintenance while paralyzed or weakened, the bone and joint physiology secondary to paralysis, and circulatory and nutritional factors.

In treating our patients, we try always to keep in mind the important general objective as well as the local one. We try to treat the individual person, not just an isolated extremity. For that reason the much advertized problem of "alienation" has never been a serious one for us. The training of the patient as well as his muscles are of almost equal importance. Briefly, our methods are as follows:

In the Acute Stage

1. Bed rest in a darkened room with complete quiet is important. Sedation is indicated for general restlessness or for pain.

2. Encouragement and reassurance are essential, not only for the patients themselves, but also for their families.

3. Protection in the form of half-shell plaster molds or "Toronto"-type splints should be provided for paralyzed, weakened, or tender extremities in positions of relaxation. In this way, physiological rest is assured for the affected muscles.

4. Frequent checks are made of muscle power within reasonable limits, to determine progress of the disease in the early days, and the results are charted. Hyperaesthesia or muscle tenderness is also checked and noted. Except in the encephalitic type, we have not had clinical evidence of spasticity in the paralyzed extremities. Stiff necks and backs are usual in the early days, but they tend to disappear spontaneously.

5. Radiant heat is administered intermittently as a painless stimulant to local circulation.

In the Convalescent Period

6. Gentle massage is administered to the paralyzed or weakened groups, and is increased slowly in depth and force as soon as hypersensitivity permits.

7. Passive motion within a limited arc is begun in joints where muscle power is below 50 per cent., and active motion is started in an increasing range, as the muscles grow in strength.

8. Graduated exercises are given for weakened muscles, in proportion to their ability, after a careful check has been made of their power. This requires skilled physio-

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 1, 1944.

TABLE I

RESULTS OBTAINED—1941 SERIES

Number and Percentage of Muscles Attaining Final Grade of 80 Per cent. or More

First Examination Grade *	Total Number of Muscles Graded	Number Attaining Grade of 80 Per cent.	90 Per cent.	100 Per cent.	Total Attaining 80 Per cent. or More	
					Number	*Per cent.*
0	64	0	0	0	0	0
5	34	2	0	1	3	9
10	34	2	0	5	7	21
20	29	8	4	5	17	59
30	50	3	3	23	29	58
40	52	4	4	33	41	79
50	29	0	8	19	27	93
60	74	3	5	63	71	96
70	50	0	4	45	49	98
80	40	0	0	39	39	98
Totals	456	22	28	233	283	62

* Based on Key to Muscle Grading (Table I)[1]. Briefly, the grades show the degree of restoration of function in paralyzed muscle groups, as achieved during interval examinations referred to in the text. The lowest grade or zero is given to muscles with no contraction, and intermediate grades up to 80 are given as function increases.

therapists with knowledge of physiological anatomy, and a quick sense of appreciation of the fatigue which comes so suddenly in partially recovered muscles. We are fortunate at the Children's Hospital School, for our staff is directed and has been trained by Mr. H. O. Kendall. He has an uncanny appreciation of muscle power and muscle fatigue, and a wonderful ability to impart his skill to others.

9. Education of the patients begins at once by getting their help in our program of protection and development. Those who seem destined to have some inescapable dis-

TABLE II

COMPARISON BETWEEN EARLIER SERIES AND 1941 GROUP

First Examination Grade	Percentage Attaining 80 Per cent. or Better		Late Group 1932–1938 (*Per cent.*)
	1932–1939 (*Per cent.*)	1941 (*Per cent.*)	
0	4	0	2
5	(Not included)	9	0
10	42	21	0
20	50	59	5.5
30	82	58	16
40	80	79	22
50	86	93	30
60	90	96	14
70	96	98	52
80	100	98	84
Percentages based on total of	701 muscles	456 muscles	103 muscles
Average over-all improvement to 80 per cent. or better	56.6 per cent.	62 per cent.	15 per cent.

TABLE III

COMPARISON OF RESULTS IN THE THREE GROUPS OF PATIENTS

Group	Number of Muscles Tested	Muscles with 20 Per cent. or More Recovery	
		Number	*Per cent.*
Group I, Lenhard (Early and adequate treatment)	701	578	82.4
Group II, Lenhard (Adequate treatment started five months to eighteen years after onset)	315	103	32.7
1941 Group (Early and adequate treatment)	456	358	78.7

ability are turned from invalidism and self-pity toward a healthy attitude of adaptability and compensation. In the wards, the children help one another to achieve this end, and are helpfully guided by staff members. It is an interesting fact that ward patients do much better in this respect than those patients in private rooms. Even the most seriously paralyzed patients improve in a more or less normal atmosphere until basic psychological adjustments can be attained.

10. Later we use underwater exercise in pools, but it is a difficult medium to use in early cases, as control of patient and affected part is less accurate, and, therefore, the danger of overfatigue is greater.

11. Our records are kept faithfully and accurately by Mr. and Mrs. Kendall, and the factor of error is less than 5 per cent. on repeated tests. It is on the basis of these charts of checks, made at least monthly during the first three months, and at least every three months during the first year, and twice a year thereafter, that our figures and conclusions are based.

One positive benefit from a crusade of the Sister Kenny type is that it makes us reexamine our own therapeutic procedures to find out if time, fashion, or carelessness have led us astray in any particular. So far we have remained unimpressed by the claims of superiority of the Sister Kenny treatment.

Certain fundamental facts about poliomyelitis should be stressed:

1. Patients are not cured; they recover, and we assist in the recovery.

2. It is more important for a badly paralyzed patient to recover to 80 or 90 per cent. of normal, than for a slightly weakened patient to make a complete recovery. Therefore,

TABLE IV

MUSCLES RECOVERING UP TO 30 PER CENT. AFTER A CONVALESCENCE PERIOD OF THREE MONTHS, AND 60 PER CENT. OR BETTER AFTER TWELVE MONTHS

First Examination Grade	Number of Muscles	Number Attaining 60 Per cent. or Better	Percentage of Functional Recovery
0	17	0	0
5	16	5	31.3
10	17	7	41.2
20	20	15	75
Total	70	27	38.6

our figures are not rated in case units, for in this way misleading statistics may be produced.

3. The proper unit is the weakened or paralyzed muscle itself, and recovery is judged on final muscle power as compared with the original degree of paralysis. Each muscle's record in each case is kept separately, and analyses and comparisons can be made with these definite units without the introduction of variables. In this way, can be determined the overall percentage of recovery, the recovery of the upper as compared to the lower extremity, the recovery of trunk and abdominal muscles, the rate of recovery, the effect of use, exercise, and other factors on recovery, and the prognosis for individual muscle recovery.

Inasmuch as these records provide us with almost astronomical figures, as they involve more than 100,000 checks on muscles, we have selected for this analysis ten commonly paralyzed and very important muscles: gluteus maximus, gluteus medius, quadriceps, hamstrings, gastrocnemius, tibialis anterior, deltoid, biceps humeri, triceps brachii, and opponens pollicis.

The figures shown in Tables I, II, III, and IV represent an epidemic in which the cases were conservatively treated, as outlined above, and include sixty-four patients of both sexes and various ages. The paralyzed muscle units reported total 456, 350 in the lower extremity, and 106 in the upper extremity.

The author's work has been chiefly an elaboration and confirmation of Dr. Lenhard's. In our analyses, a period of ten years has been covered, so it may be considered fairly representative of poliomyelitis in our section of the country.

CONCLUSIONS

1. All muscles, even in a widespread, complete paralysis of entire extremities, should have three months of careful and painstaking protection and treatment comparable to that given in peripheral-nerve lesions.

2. At the end of such a three months' regimen, a very accurate prognosis of recovery can be arrived at, for the muscles can then be differentiated into three categories:

a. Those which have not recovered to a point of 30 per cent. of power in three months. No return of useful power is to be expected; and these make up the group of the permanently paralyzed extremities.

b. Those which by this time have 80 per cent. or more power, and can be counted on to function satisfactorily without any further treatment except general supervision.

c. The group which has demonstrated some return of power and has a three-month level of 30 to 75 per cent. These have potentiality for further recovery to a point where useful function can be restored. These cases are the crucially important ones as far as further active treatment is concerned, and every effort should continue to be expended on this group to build up power and develop hypertrophy of the active muscle tissue persisting, and to protect these patients against overfatigue and postural strain during at least the next year.

3. No appreciable recovery continues beyond eighteen months, even under ideal conditions, but untreated or inadequately treated cases have been salvaged by this regimen as late as six to ten years after the acute attack, indicating a previous nerve recovery which had been masked or nullified by the overstretching or overfatigue of the muscle or by opposing contracture.

4. On occasions we have observed loss of power in muscles of our own cases from overfatigue and too early removal of support, with permanent damage in some few instances, again demonstrating the need for careful supervision during recovery.

1. LENHARD, R. E.: The Results of Poliomyelitis in Baltimore. J. Bone and Joint Surg., XXV, 132, Jan. 1943.

BULLET FRACTURES OF THE LONG BONES

BY MAJOR HIRA E. BRANCH

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Bullet fractures of the long bones require more careful treatment than any other serious fracture. The purpose of this article is to emphasize the importance of conservatism in the débridement and management of such fractures.

The term "bullet fracture" is used to denote a compound shattering of a long bone (Figs. 6-A, 6-B). While any sudden severe injury may result in a fracture of this type (Figs. 3-A, 3-B), a bullet or a fragment of metal casing from an explosive missile is the usual cause. The fracture resulting from a direct hit by a high-velocity bullet is typical, and is characterized by multiple small fragments of bone in a compound wound.

The Office of the Surgeon General has outlined the principles of wound treatment in Circular Letter Number 178, dated October 23, 1943:

"1. Adequate exposure in order to permit access to all parts of the wound. . . . Very little skin need be excised, but good exposure may necessitate longitudinal incision of the skin and the fascia planes.

2. Removal of:
   a. Readily accessible foreign bodies. . . .
   b. Particles of bone completely separated from the periosteum.
   c. Tissue that is soiled, devitalized, or the circulation of which is impaired. . . .

3. Leave wound open.

4. Dressing should be placed loosely in the wound, not packed.

5. In large wounds, immobilize the part by adequate splinting, even in the absence of fractures."

Three of these principles are of particular importance: (1) removal of only those bony fragments which are completely separated from the periosteum; (2) placing of dressings loosely in the wound; (3) complete and prolonged immobilization.

The utmost caution should be observed in the débridement of bullet-fracture wounds. Loose and completely detached particles of bone should be removed, but bony fragments with periosteal and soft-tissue attachment should be left undisturbed, so that they may act as struts or live bone grafts for the restoration of the shaft of the bone. The result is a tremendous saving in time and function, and often of the limb itself. Fragments at-

FIG. 1

Bullet fracture of femur caused by forty-five caliber revolver bullet. Roentgenogram taken after six weeks, when manipulation was attempted to correct posterior bowing. Fracture was so solid correction was not obtained. There was no deep drainage from the two granulating wounds.

FIG. 2-A

Bullet fracture of femur caused when soldier's motorcycle collided head on with truck during a blackout.

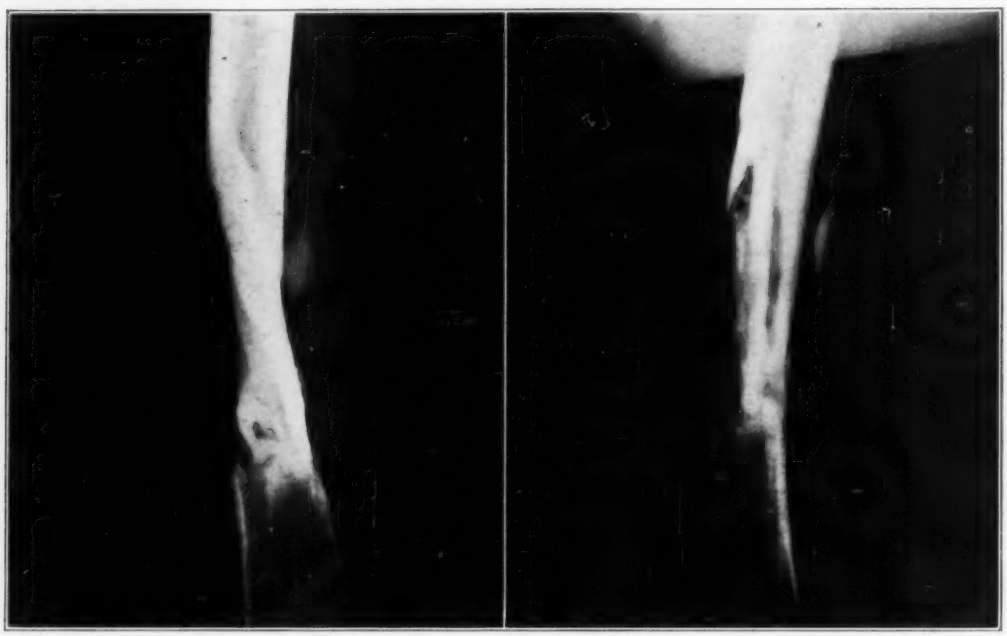

FIG. 2-B

Shows solid healing of fractured femur after ten months. Patient has been walking in a caliper brace for one month. Anterior bone fragment projected into the quadriceps, and has been removed to facilitate quadriceps and knee motion.

tached to the periosteum rapidly set up a barrier to infection, whereas removal of the fragments, instead of preventing or arresting deep infection, creates a dead space in which

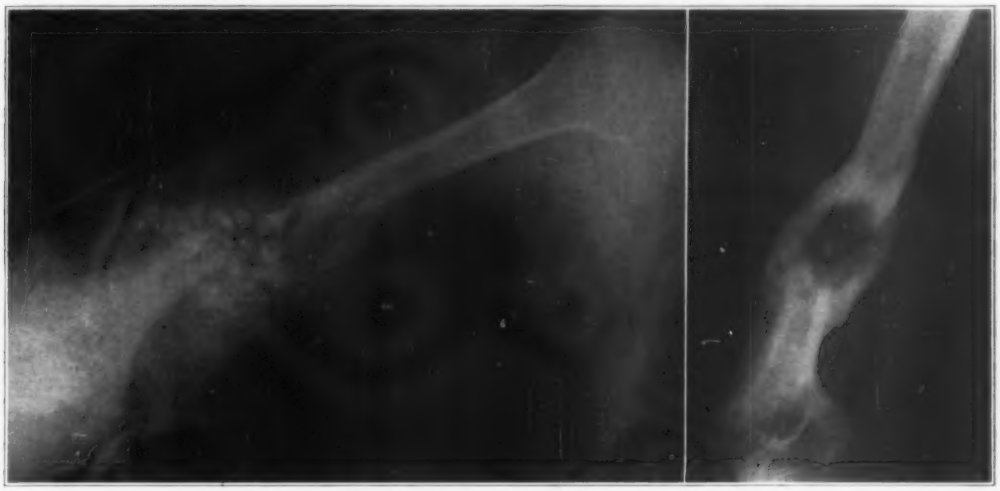

FIG. 3-A FIG. 3-B

Fig. 3-A: Fresh bullet fracture of humerus caused by Japanese rifle bullet.
Fig. 3-B: Shows degree of healing six months after injury; two small sinuses, one anterior and one posterior, persist. A small sequestrum is present in dead space of bone.

FIG. 4

Roentgenogram taken six weeks after humerus was shattered by German machine-gun bullet. Degree of healing was very fast. Wounds have healed except for dime-sized pouts of granulation tissue at points of entrance and exit of bullet. Hanging cast was removed at this stage.

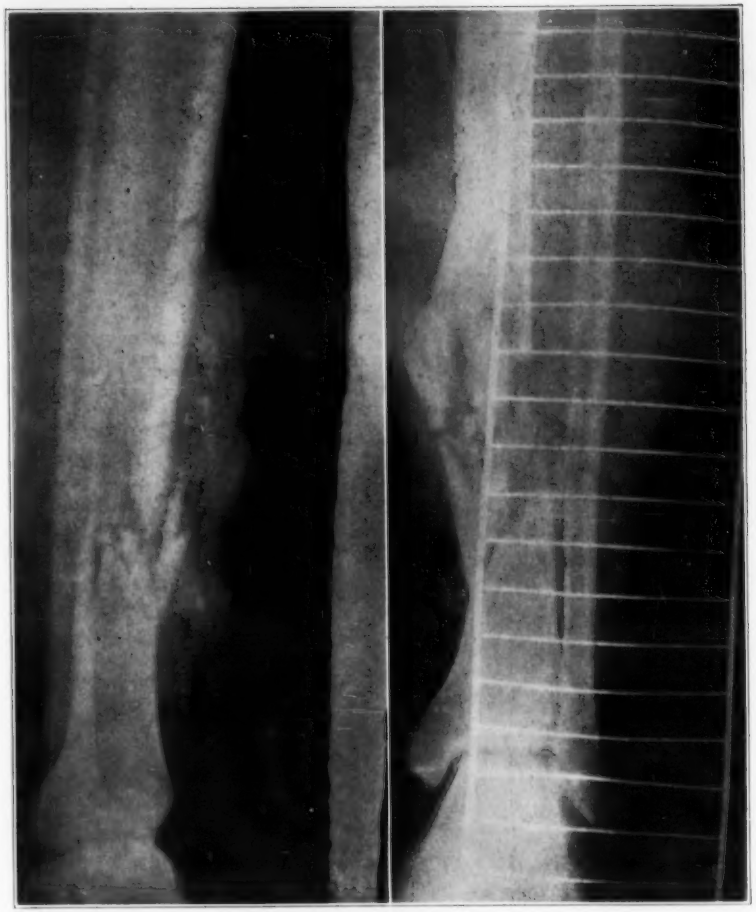

FIG. 5-A

Bullet fracture of tibia caused by enemy rifle bullet.

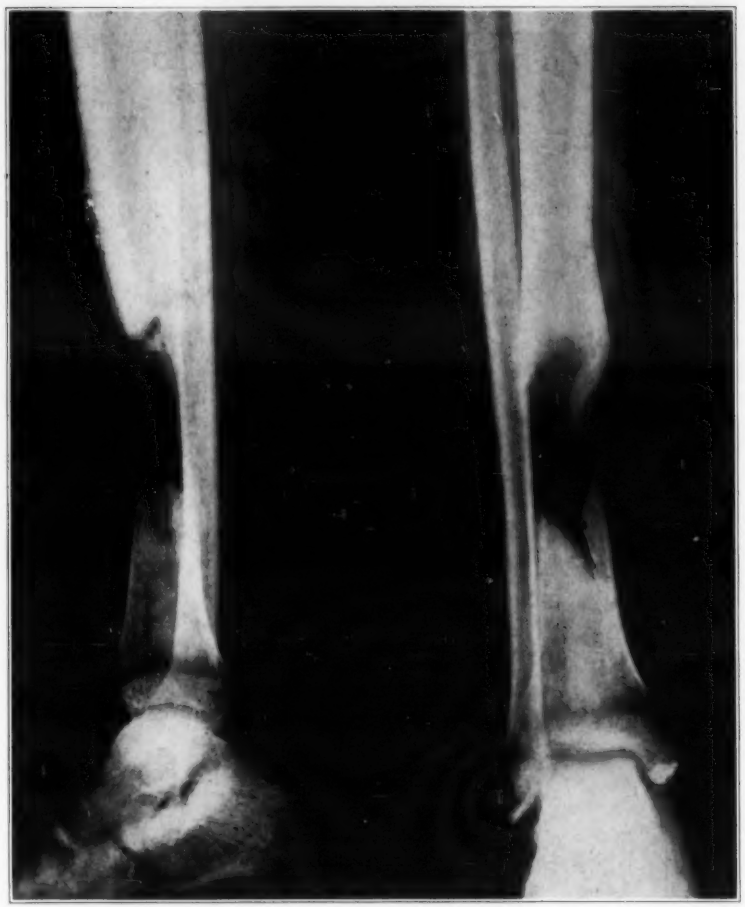

FIG. 5-B

End result six months after overzealous débridement and removal of all bony fragments. Notice complete loss of tibial shaft and small rarified areas of osteomyelitis. A persistent draining sinus delayed bone reconstruction. Amputation was advised.

infection persists for a long time. Thus bone-graft or reconstructive procedures are delayed until long after the time in which the fragments would have fused of themselves, and would have formed an entire, or at least a partial, new shaft. Often, after such radical removal of fragments, amputation is the only means to rehabilitation.

Non-metallic foreign bodies which are readily accessible should be removed, but a search for all metallic particles is unnecessary, and may do more harm than good. Many metallic particles are deeply buried in muscle and rapidly become walled off, after which they cease to prevent healing (Figs. 7-A, 7-B).

After a conservative débridement, a fine mesh gauze pack, heavily impregnated with vaseline, should be loosely inserted at the bottom of the wound, thus facilitating drainage. Fortunately, in most cases, drainage is slight and rapid wound healing occurs. If the wound is packed tightly, the formation of pus pockets may destroy the many viable bony fragments, and non-union with osteomyelitis may result. On the other hand, if loose packing is not inserted, the muscles and skin may heal superficially, closing the wound prematurely. Deep-tissue infection with pus retention may result and be extremely serious.

The affected parts should be completely immobilized for a long period, and, occasionally, traction in plaster is necessary to maintain the length of the bone. Changes of cast should be infrequent, to obviate the danger of breaking or disturbing the delicate callus and bony struts which form in a surprisingly short time. If these are broken or if lateral stress is placed upon them, non-union may result.

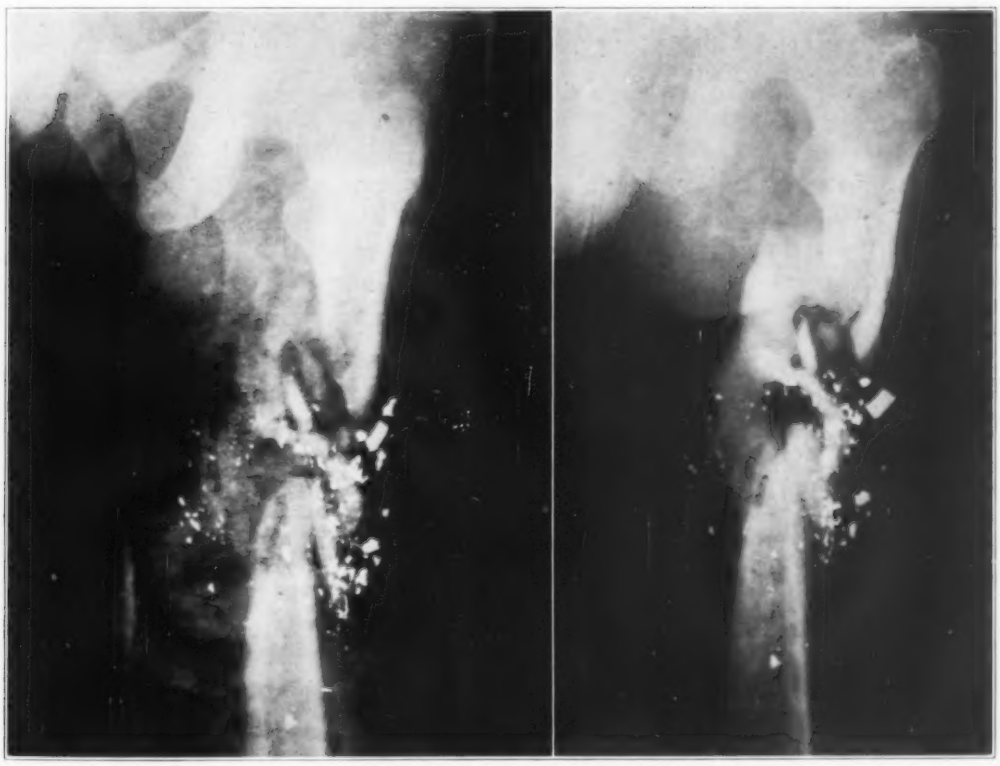

FIG. 6-A FIG. 6-B

Fig. 6-A: Severe bullet fracture of femur caused by thirty-caliber machine-gun bullet at a distance of three feet.

Fig. 6-B: Roentgenogram taken ten months later shows the enormous reconstructive power of these shattered fragments of bone if left alone, in spite of the presence of metallic particles in the soft tissues. Wound has healed but for a pea-sized sinus. Patient has walked for the last six weeks in walking caliper brace.

FIG. 7-A

FIG. 7-B

Fig. 7-A: Fresh bullet fracture of ulna, caused by fragments of German shell.
Fig. 7-B: Roentgenogram taken after five and a half weeks shows wounds healed; fractures clinically solid in spite of the metallic fragments in the tissues.

A few illustrations selected from a large series of patients are presented to show the tremendous restorative powers of bone healing and reconstruction of which Nature is capable, if not interfered with unwisely. Amputation of many extremities has been avoided by the recognition of these principles.

THE INTERVERTEBRAL DISC: ITS MICROSCOPIC ANATOMY AND PATHOLOGY

PART II. CHANGES IN THE INTERVERTEBRAL DISC CONCOMITANT WITH AGE

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In a preceding article [3] we presented the first of three studies on the intervertebral disc. The purpose of these studies and the methods and material used were explained. The anatomy, embryology, and physiology of the intervertebral disc were reviewed, our own specimens being used to substantiate or disprove the accepted ideas along these lines. The present paper deals with the microscopic changes observed during the aging process.

The body passes through a degenerative cycle which is reflected in all its tissues. This change, which is part of the aging process, begins even at birth. During the earlier years of growth and development, these degenerative or retrogressive changes are insignificant as compared with progressive or developmental changes. But, as growth slows down, retrogression speeds up, and in later years finally dominates. All the body tissues are affected by these downhill changes, some much more than others. The intervertebral discs, of course, follow this pattern of progression and retrogression. It is evident that they are affected early and retrogress more rapidly and severely than do most of the other tissues. This is usually explained on the basis of excessive wear and tear. At all times, the intervertebral discs are actively functioning. They are subject to a great deal of traumatic insult. Their constant use, as well as their susceptibility to trauma, and their relatively poor blood supply, doom the intervertebral discs to early and advanced degenerative changes. The following changes have been observed in the respective decades.

FIRST DECADE

In the first decade of life many developmental changes take place. The intervertebral discs are in a stage of progression, not of retrogression. Five specimens have been studied from subjects ranging in age from ten months to seven years. Changes will be recorded under the three headings: cartilaginous plate, annulus fibrosus, and nucleus pulposus. Figure 1 represents a typical disc of this first decade.

A. *Cartilaginous Plate*

The cartilage cells are round to oval and very clear microscopically. They are hyaline in type. The matrix stains deeply and is homogeneous. The cartilaginous plate itself extends over the entire end surface of the vertebra, and downward anteriorly and posteriorly for a short distance.

Up to the age of six years the specimens show hyaline cartilage dipping into the bodies of the vertebrae. In the ten-month specimen there is complete sagittal separation of the posterior sixth of the body from the remaining anterior portion by a band of cartilage extending between the two cartilaginous plates. Ossification is present along its vertebral margins, which is actually the epiphysis of the vertebral arch. It gradually decreases in size to thin out and disappear by the tenth year.[9]

At the edge of the cartilaginous plate, adjacent to the cancellous bone of the vertebrae, is the ossification layer, in vertical rows of columnar cells. Here endochondral growth of the vertebral body takes place. The inner margins of this layer are wavy in outline. Here and there (Fig. 2) are "ossification gaps", the importance of which has been empha-

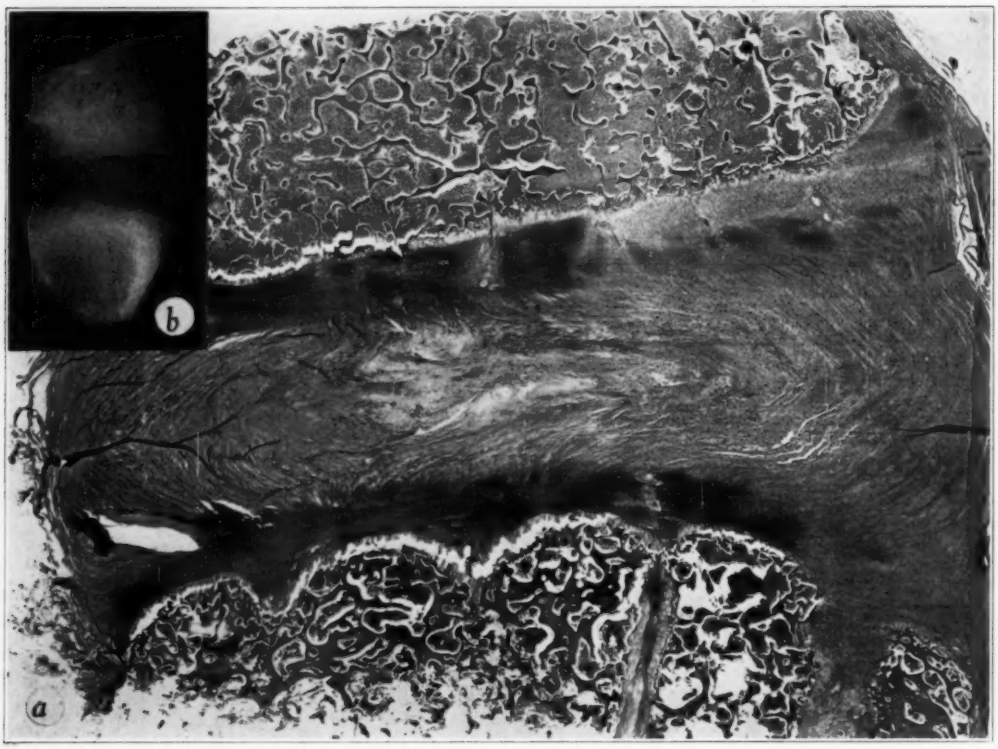

FIG. 1

Intervertebral disc of a boy, aged six years. *a.* Section (× 6). *b.* Roentgenogram.

sized by Schmorl. He expressed the belief that they correspond to the perforations in the end plate, as previously described. These gaps occur most commonly at about eight years of age and have horizontal bands of fibrillated cartilage matrix running across them. In the adult, all evidence of these gaps disappears, but they may be weak points, first affected by stress and strain.

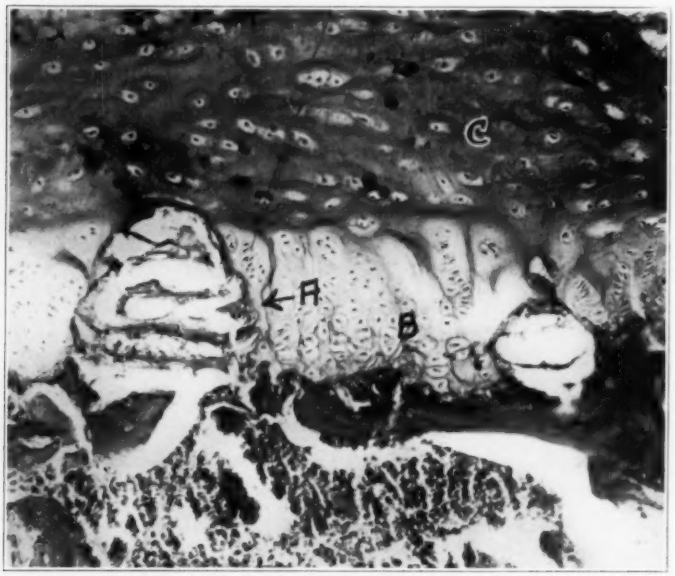

FIG. 2

Photomicrograph (× 115) showing portion of an intervertebral disc of a girl, aged seven years. *A:* Ossification gap. *B:* Ossification layer of cells. *C:* Cartilaginous plate.

In the very early ages, numerous vascular channels are seen imbedded in and perforating the cartilaginous plates from the vertebral side. By the age of ten years, these channels have largely disappeared, though they may remain to the age of twenty years.[1] Übermuth in 1929 and Böhmig in 1930 were the first to stress the importance of these vessels. The specimens in this study confirm the fact that the origin of these channels is the spongiosa. Fi-

brosis, followed by invasion by cartilage cells, obliterates these channels at an early age. Scars of these channels remain throughout the life of the disc. These obliterated channels may be areas of weakness, predisposing to herniation of material from the nucleus pulposus.

Evidence of congenital or developmental defects in the cartilaginous plate is lacking in this study. The ossification gaps and vascular channels already mentioned are the only factors found predisposing to nuclear protrusion. No true splits or open defects have been found. The fact that they are found in later life may be accounted for on the basis of artefacts. (In the spinal columns of young subjects, the cartilage and bone are soft, allowing easier section with the microtome knife than in older specimens; consequently there is less crushing and tearing.)

FIG. 3

Roentgenogram of vertebrae and intervertebral disc of same subject as Fig. 2. *A*: Ring containing cartilaginous epiphysis.

Schmorl stated that ossification centers appear in the epiphyseal ring as early as the eighth year. The epiphyseal ring could be seen roentgenographically, in one of our specimens from a subject, aged seven years (Fig. 3). The superior and inferior anterior vertebral margins are characteristically notched.

B. *Annulus Fibrosus*

Übermuth has expounded the hypothesis that the components of the intervertebral disc grow and change according to the stress and strain brought on by the changes in age, with resulting changes in function. Thus, the annulus has developed by the age of six months, for the child is beginning to sit up and needs the spinal column for support. Our earliest specimen, that of a ten-month-old infant, shows the annulus quite well developed (Fig. 2, Part I).[3] The fine strands of fibrous connective tissue with their long, narrow nuclei are arranged in bundles or lamellae, running for the most part parallel, but in places interwoven.

As the age of the subject increases, the annulus begins to attach itself to the newly developing anterior and posterior longitudinal ligaments. Stress and strain begin their formative function and the lamellae take a slightly different course as they stream off of the cartilaginous plate. The open spaces between the lamellae fill up with a ground substance, and by the tenth year the annulus has completely developed as a compact, retaining structure.

C. *Nucleus Pulposus*

We must always think of the nucleus pulposus as an active, living structure vitally concerned with body mechanism. During the first decade the nucleus develops rapidly. Chordal remnants—cells and gelatinous matrix—tend to disappear. Most authors describe the presence of chordal cells,—large, pale-staining, multinuclear cells with vacuolated cytoplasm. (None of these cells was found in the specimen from the ten-month-old subject.) Fibroblasts in large numbers are seen, as well as cartilage cells, especially around the periphery.

The shape of the nucleus in the specimens from very young subjects is more rectangular than oval. As the subject grows older, however, the oval shape is assumed. The fine, interlacing fibrils in their delicate ground substance of amorphous, mucoid material seem to grow coarser toward the end of the first decade. Vacuoles in large numbers occur, as well as large, irregular spaces in the nucleus. These spaces are often thought of as central cavities, analogous to joint spaces. No evidence of endothelial lining has

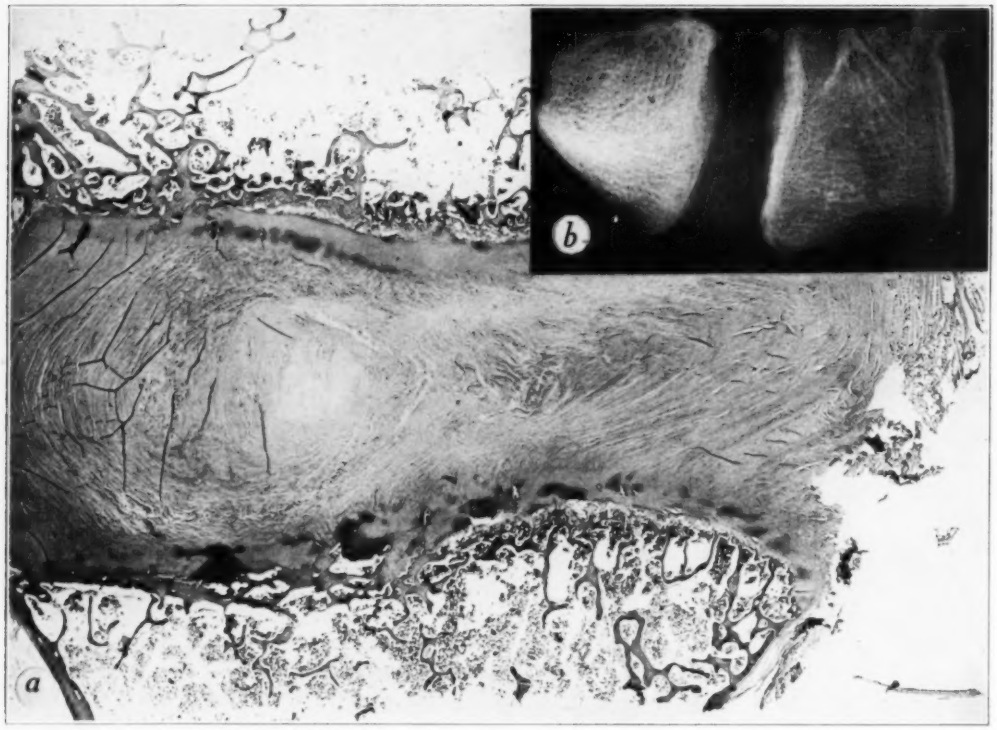

FIG. 4

Intervertebral disc of a youth, aged sixteen years. *a*. Section (× 4). *b*. Roentgenogram.

been observed, although an acellular, flattened, darker-staining lining is often present. This may be due to deposition of stain or to the concentration of amorphous material contained in these cavities. Saunders and Inman expressed the opinion that these cavities are probably evidence of desiccation of the nucleus. Our study tends to support this view. In fact, the cavities may be only artefacts.

Is there true mucin in the nucleus pulposus of the intervertebral disc? Deucher and Love, among others, have found evidence of mucin in posterior protrusions of a disc removed at operation. They used mucicarmine stain to demonstrate it. De Galantha's mucin stain was used in the present study. No section showed the presence of mucin with this stain, though there is a characteristic bluish reaction in the nucleus pulposus to hematoxylin and eosin which certainly suggests that the ground substance of the nucleus is a mucoid material.

SECOND DECADE

In the second decade progressive changes are still occurring, but in the later years the picture of the adult disc is reached. Figure 4 shows a typical disc of this period.

A. *Cartilaginous Plate*

Growth of bone continues from the base of the cartilaginous plate, although it has slowed up a great deal toward the end of this decade. After the age of fourteen to sixteen years, the cartilaginous plate rapidly becomes less active than before. At the age of twenty years, only very few cells of endochondral growth are found. The ossification gaps persist as long as ossification continues. An increase in the deposition of bone at the vertebral bony end plate is found during the middle of the second decade.

A specimen from a youth, aged nineteen years, shows fusion of the epiphysis to the body of the vertebra. However, in none has a section included an ossification center in

the epiphyseal ring. The cartilaginous plate in the specimens from younger subjects extends to the edge of the vertebra anteriorly and posteriorly, but after fusion of the epiphysis to the body, the cartilaginous plate ends abruptly at the edge of the epiphysis, and annulus fibers stream over the bony rim formed by the ossified epiphyseal ring, to insert into the longitudinal ligament and into the vertebral bone itself.

FIG. 5

Photomicrograph (× 25) showing portion of an intervertebral disc of a youth, aged twenty years. *A:* Nucleus pulposus. *B:* Cartilaginous plate. *C:* Multiple nuclear protrusions.

Many vascular channels are still present. They are seen to be filled with blood and penetrate deeply into the cartilaginous plate. These channels diminish as age progresses and none of the specimens in this study beyond the age of nineteen years shows them. The scarring of these channels has been described previously.[3]

During this decade the cartilaginous plate has become somewhat thinner than before, and the cells have taken on a more mature appearance. The ossification of the plate has almost stopped. The cartilaginous plate has fused anteriorly and posteriorly to the epiphyseal ring. In all, it has reached its maturity and almost the end of its phase of progression and development.

Retrogression has taken place during this decade. Perhaps the curves of progression and retrogression cross at about the age of eighteen years, when the two are at a balance. At least, from this decade on, degenerative processes advance rapidly. No true Schmorl's nodules were found in our specimens before the age of twenty years. One specimen, from a male subject, shows some multiple microscopic protrusions (Fig. 5), one of which can be seen grossly. Most of them are found at the peak of the expansion of the nucleus, a point that will be discussed later.*

Several longitudinal fissures are seen in the cartilaginous plates in this decade. They are probably artefacts, not to be mistaken for congenital defects, although Beadle expressed the belief that they may be developmental.

Roentgenograms of these specimens are all normal except for the previously mentioned twenty-year-old male subject. This is a good example of a nuclear expansion and also of a Schmorl body. No hypertrophic lipping is evident in any roentgenograms in this series during the first two decades; also no thinned discs are observed.

B. *Annulus Fibrosus*

Progression is probably still taking place in excess of retrogression in the annulus fibrosus of this decade. As stress and strain are applied to the disc during the vigorous activity of youth and young adulthood, the annulus must be further strengthened to serve its purpose as a limiting structure for the nucleus pulposus. Whereas during the first decade of life the fibers were more discrete and the lamellae tended to be separated

* In Part III, to be published.

from each other by slight gaps, in this decade the lamellae are tightly packed together, functioning more as a whole. Growth of annulus fibers from the cartilaginous plates has progressed, and there is more annulus superiorly and inferiorly between the nucleus and the cartilaginous plate.

The epiphysis has fused, in many instances, to the underlying vertebrae in the latter part of this decade. The annulus fibers, in these cases, have anchored themselves to the bony rim of the epiphysis; some have passed over it, merging with the longitudinal ligaments.

In the later years of the second decade, however, there is evidence of degeneration. The fibers comprising the annulus become less distinct; the number of nuclei seems to decrease; and early hyalinization can often be observed.

C. *Nucleus Pulposus*

Development is still taking place in the nucleus pulposus during the second decade. The fluid content is increasing as the nucleus responds to its increased functional rôle. The loss of the diffuse character of the nucleus is noticeable. Whereas during the first decade the nucleus is a general admixture of cells, fibrils, and semigelatinous ground substance, it now becomes more broken up and irregular. A central cavity sometimes appears. This cavity does not have a cellular lining and is probably central debris lost during sectioning, though some writers look on it as a rudimentary joint space.

Around the periphery the nucleus becomes somewhat more cellular,—chiefly cartilage cells, in pairs and in nests. Fibrils remain in the nucleus but they are seen in clumps. Parts of the nucleus have a new granular appearance. Vacuoles are still seen. The line of demarcation separating the nucleus from the annulus becomes somewhat more distinct during the second decade. This is another indication that the differentiating process is taking place and that the nucleus is maturing and growing to its adult functioning form.

THIRD DECADE

In this group of eight there are two specimens which showed evidence of disease. One, from a twenty-nine-year-old woman, shows roentgenographic as well as gross evidence of definite thinning of the disc. The other, from a thirty-year-old man, is a classic example of a nuclear expansion. (These two cases will be discussed in Part III.) Figure 6 represents a typical disc of this decade.

A. *Cartilaginous Plate*

Developmental changes are still going on at the beginning of this decade, but to a lesser degree. While there are a few islands of bone-forming cells at the base of the cartilaginous plate, it has for the most part ceased its growth function. The epiphyses that have not already united do so at the beginning of this decade.

What retrogressive changes are taking place? The processes of wear and tear, of repeated trauma, begin in earnest during the active period of young adulthood. Degenerative age changes, *per se*, are commencing. However, the changes are early, and microscopic evidence is not abundant. A few specimens do show beginning fibrillation of the cartilage. Also, longitudinal fissures are occasionally seen. These, for the most part, are probably artifacts; though they may occasionally be results of trauma. They do not, as a rule, show evidence of repair. A few specimens, however, do show fibrous invasion, proving that some of these fissures are premortem. These repaired tears are seen best with the van Gieson stain.

The cartilage cells during this decade show occasional signs of degeneration, though for the most part they are clear in outline and have normal nuclei. The width of the cartilaginous plates seems slightly less than before, as suggested by Donohue, though this is hard to evaluate. A few remaining vascular channels are seen in some of the speci-

FIG. 6

Intervertebral disc of a woman, aged twenty-one years. *a*. Section (× 4). Most of the nucleus pulposus has dropped out during sectioning. *b*. Roentgenogram.

mens of this decade. The zone of calcification at the junction between cartilage and bone is becoming more distinct than it was earlier.

Only two of the eight specimens in this group show evidence of breaks in the cartilaginous plate with protrusion of nuclear material through the breaks. These breaks are seen in increasing number as age progresses, and are a definite indication of the degree of the degenerative changes occurring in the disc. The microscopic protrusions of the nucleus pulposus into the adjacent vertebrae will be discussed in detail in Part III.

B. *Annulus Fibrosus*

During this decade the changes accompanying wear and tear seem to appear to the greatest extent in the annulus. The fibers become coarse and hyalinized, and a concentric fissuring of the lamellae occurs. Cellular detail is almost lost. One specimen in this group shows a moderate amount of oedema between the lamellae.

Deucher and Love, examining specimens of protruded discs removed at operation from patients of various ages, found degeneration of cartilage cells in 32 per cent. This was demonstrated by loss of cell outline and pyknosis of the nuclei. The specimens studied in this decade alone show at least this high a percentage of degenerative changes in the fibrocartilage cells of the annulus.

C. *Nucleus Pulposus*

The nucleus is no longer mucoid in appearance. The general composition is of several cavities of various sizes, in a loose, fibrillar network. At the periphery are heavier fibers and many more cartilage cells than were seen in the previous decade. Some of these nests contain ten to fifteen cells. The nucleus begins to blend more intimately with the annulus, as stressed by Saunders and Inman. During the first decade the two were indistinct. During the second decade, the nucleus seemed to differentiate and separate

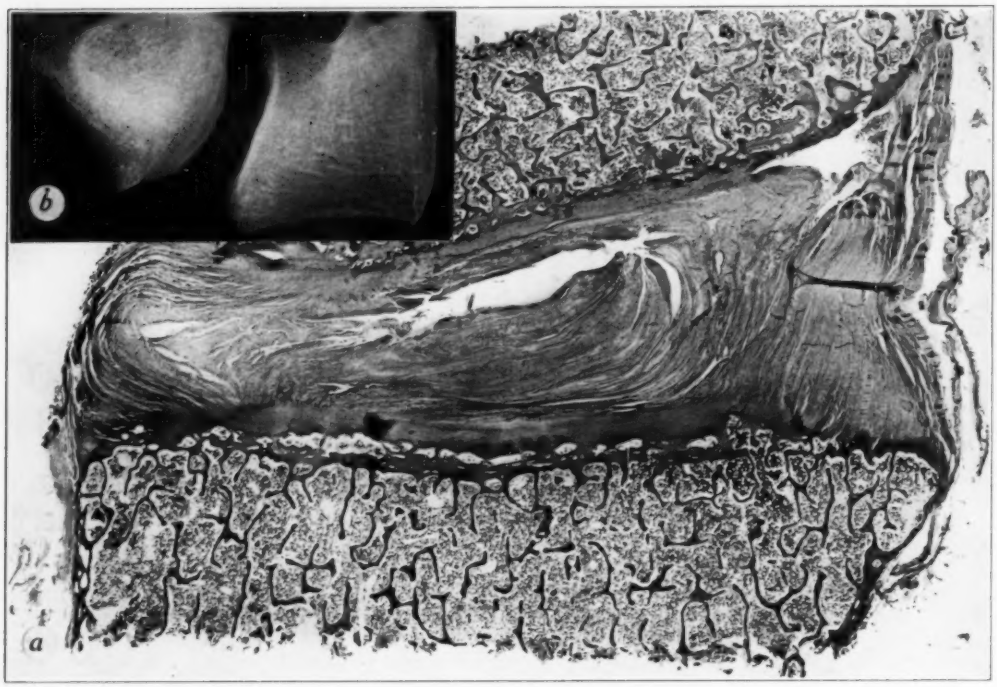

FIG. 7

Showing intervertebral disc of a woman, aged thirty-five years. *a*. Section (× 4). *b*. Roentgenogram.

from the annulus. But during the latter part of this third decade, it is again no longer distinct from the annulus.

According to Übermuth's hypothesis of adaptation, during the third decade the disc is at its maximal point of function. Beadle quoted Übermuth as follows: "At this stage the disc has a uniform soft buffer action and elasticity; it is the high-water mark of the swelling process and from then onward there is the steady loss of fluid characteristic of age".

FOURTH DECADE

Nine specimens were examined in this group. One showed thinning, one showed nuclear expansion, and five showed microscopic evidence of nuclear protrusions into the spongiosa of the vertebral body. Thus we see that pathological lesions are increasing in number and keeping pace with the degenerative changes of age. Figure 7 represents a typical disc of this age group.

A. *Cartilaginous Plate*

It is very striking to see the severe retrogressive changes that have occurred in this decade. The degenerative defects in the cartilaginous plate range from thinning to complete absence of cartilage in places. Many microscopic protrusions of the nucleus pulposus are evident. In several places there is evidence of bony invasion of the cartilaginous plate from below, with blood channels and marrow elements penetrating into the nucleus. This erosion from the marrow spaces has been described in detail by Saunders and Inman.

The cartilage has lost its even texture in this decade and for the most part takes a rather mottled, irregular stain. There is a definite increase of deposits of calcium salts at its base. Fibrillation is more evident and in places almost completely destroys the normal cartilage.

Why defects in the cartilaginous plate—fissures and tears through which nuclear material extrudes—should appear at this age has been a point of controversy. Donohue

expressed the belief that the cause is a congenital fault, plus a tear from trauma. The only congenital fault that we have been able to demonstrate, however, is the blood vessel channels that penetrate the plate in the first decade and later sclerose. These, we feel, are the chief regions of weakness, at which in middle age protrusion may occur from trauma.

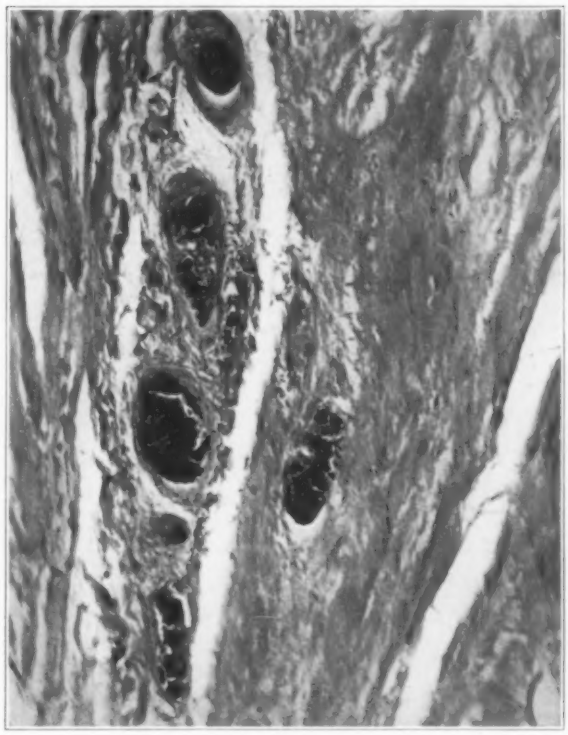

FIG. 8

Photomicrograph (× 145) showing blood vessels in the posterior portion of the annulus fibrosus of a woman, aged thirty-five years.

B. *Annulus Fibrosus*

Degenerative changes are more marked during this decade than at earlier ages. In addition to fissuring, hyaline degeneration, increase of nests of cartilage cells and nuclear pyknosis, two new phenomena appear. One, that of pigmentation, is seen in one of the specimens of this group. The pigment is finely granular and takes a reddish-brown stain with hematoxylin and eosin and a yellow stain with van Gieson's. It is arranged in long oval streaks between the lamellae. Its exact composition and nature are unknown but, since it makes its appearance as age progresses, it is probably a result of degeneration.

The second change to make its appearance in this decade is that of vascularization of the annulus. This was first observed in this study in a specimen from a woman, aged thirty-five years (Fig. 8). Several small thin-walled blood vessels were imbedded in the medial layers of the posterior portion of the annulus. They were grouped together and their lumina were filled with blood cells. This invasion of the fibrocartilage of the annulus by blood vessels may be an attempt on the part of the body to strengthen and nourish a structure which has become weakened and degenerated.

C. *Nucleus Pulposus*

The gradual loss of fluid in the nucleus has been described in detail by Püschel. This loss of fluid is evident microscopically. The soft, lacy appearance of the nucleus has given way to a mass of fibrous tissue and cartilage cells. During this decade the replacement of the nucleus with fibrous tissue is very evident. Only in occasional sections can one see the remains of the semigelatinous ground substance and the fibrillar reticulum. The distinction between the nucleus and the annulus has become less marked than it was. It appears as though the body were attempting to make the disc one solid fibrocartilaginous mass. Several of the sections show a loss of the center of the disc. This has probably fallen out during preparation,—an indication of the crumbly, dry nature of the nucleus.

FIFTH DECADE

There are eleven specimens in this group. Of these eleven, four showed evidence of disease. There is an example of "ballooning", one of thinning, one of nuclear expansion,

FIG. 9

Intervertebral disc of a man, aged forty-five years. *a*. Section (× 3.5). *b*. Roentgenogram.

and one showing a Schmorl body large enough to be seen with the naked eye. In addition, eight of the eleven specimens have defects of the cartilaginous plate with microscopic prolapse of the nuclear material into the body of the vertebra. Figure 9 represents a typical disc of this decade.

A. *Cartilaginous Plate*

One is struck by the advanced degeneration of the cartilaginous plate in this group. There is hardly one that anywhere approximates the appearance of a cartilaginous plate in the younger-age groups. Most conspicuous, perhaps, is the number of microscopic protrusions of disc substance through defects in the plate. These protrusions can be seen just entering the cartilaginous plate or may be at any stage in penetration. Very few go deeply into the bone, usually stopping at the bony plate. These protrusions suggest that the cartilaginous plate is losing its resistive power.

Besides protrusion of the nucleus, there are numerous examples of erosion of the cartilaginous plate by the bone marrow. These marrow erosions may extend well into the nuclear substance but usually stop somewhere in the plate. What determines the direction of the protrusion—from the disc out, or from the vertebrae in—must depend chiefly on the existing forces on each side of the cartilaginous plate. This balance must be determined in turn by the amount of turgor in the nucleus pulposus, for the potential force of the marrow spaces is probably constant.

Fibrillation of the cartilaginous plate is rather marked in several specimens. One specimen exhibits advanced oedema and loss of cellular outline. As a rule, however, the cartilage cells are still quite normal in appearance.

Numerous clefts and fissures are found in specimens from this decade. The majority are probably artefacts. Some are definitely antemortem, however. One specimen (Fig. 10) shows a zigzag vertical tear, filled with fine fibrinous material and a few fibroblasts. Such proved tears—proved by evidence of repair on the part of the body—are rare.

Variations in thickness of the cartilaginous plate are rather striking in this decade. In some regions the plate is entirely gone. Is this an acquired defect or a defect in development? Probably the former, as it is not observed in our younger specimens. At these points of thinness or absence, the nuclear material may or may not have protruded into the underlying bone.

FIG. 10

Photomicrograph (× 70) showing healed tear in cartilaginous plate of man, aged forty-three years.

B. *Annulus Fibrosus*

Degenerative changes continue to progress. Hyalinization is well advanced in many specimens. The lamellae are blended together in a nondescript, fibrous mass, their outlines being mere shadows. Pyknosis and even disappearance of the nuclei are common. Many of the fibrils are short, thick, and swollen. In fact, several of the sections show oedema fluid in small vacuoles scattered through the annulus.

There are many regions of new cartilage cells. Whereas in the preceding sections they were all in groups or "pearls", in some sections in this decade they are in columns, corresponding in direction to the lamellae.

Fissuring of the annulus is conspicuous. Occasional new blood vessels are seen, as in the preceding decade, but this is by no means common. Many of the sections have lost the anterior fibers of the annulus in preparation. The posterior fibers, however, are intact. No posterior nuclear protrusions are seen in this decade.

C. *Nucleus Pulposus*

The confines of the nucleus can still be distinguished in most cases in this group. However, the distinction is fast becoming less and less apparent. A gradual fibrous replacement of the nucleus is going on. The typical section in this decade shows the nucleus to be of almost the same consistency as the annulus, except that here and there are remnants of the fibrillar reticulum. The fibrous cells, of course, are not arranged concentrically as in the annulus, but pass through the nucleus in an apparently indiscriminate fashion.

More cartilage cells in groups are seen than at earlier ages. One rather marked change is the amount of amorphous debris, both in clumps and finely scattered throughout the nucleus. Many sections show pigment, as first observed in the preceding decade. Oedema is present in a few cases. While there is still evidence of a semigelatinous consistency to the nucleus, this is fast disappearing as the nucleus becomes replaced by fibrous tissue, cartilage, and amorphous material.

SIXTH DECADE

It was in this decade that Deucher and Love found the greatest amount of degeneration in specimens of protruded discs removed at operation. It is true that in the postmortem specimens reviewed in the present study the amount of degeneration had gradu-

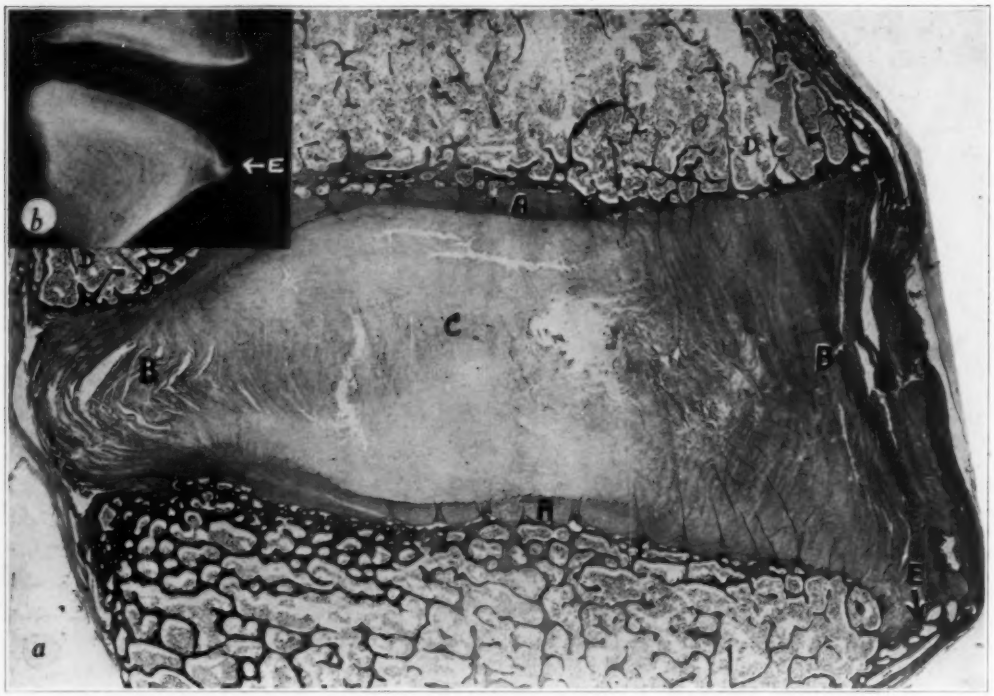

FIG. 11

Intervertebral disc of a man, aged fifty-four years. *a*. Section (× 3.25): *A*, cartilaginous plate; *B*, annulus fibrosus; *C*, nucleus pulposus; *D*, bony rim; the arrows indicate junction of the cartilaginous plate and the bony rim; *E*, bony spur. *b*. Roentgenogram.

ally increased until at this decade it is more advanced than in any preceding decade.

Of the twenty-two specimens in this age group, eighteen have demonstrable defects of the cartilage with nuclear protrusion. In addition, three specimens showed microscopic evidence of posterior protrusion of the disc. Three specimens showed thinning of the disc, substantiated by the roentgenographic appearance. In two cases Schmorl bodies were seen in the gross. There were one case of "ballooning" and one case of nuclear expansion. In several cases there was evidence of hypertrophic lipping. These will all be discussed in Part III, but they show that the curve of the incidence of diseased discs rises with the increase in age. A disc typical of this decade is represented in Figure 11.

A. *Cartilaginous Plate*

The most striking characteristics of the cartilaginous plate in the sixth decade are evidence of old, calcified, "healed" nuclear protrusions through the cartilaginous plates; heavy deposits of calcium; and advanced destructive and degenerative changes in the hyaline cartilage comprising the plate.

Rarely does a disc not show several defects in the plate through which nuclear material has streamed. Calcification is the most common defect seen at this age. The protrusion is composed of old cartilage cells, some fibrous tissue, a few blood vessels, and much calcium salt. These defects often have bone marrow growing into them from below, meeting the cartilage that has replaced the nuclear material. There are also a few recent protrusions into the spongiosa, usually small, and occurring most commonly near the border between the epiphysis and the cartilaginous plate, some actually penetrating well into the bony rim.

Calcium is deposited in large plaques and masses in the old protrusions, as mentioned

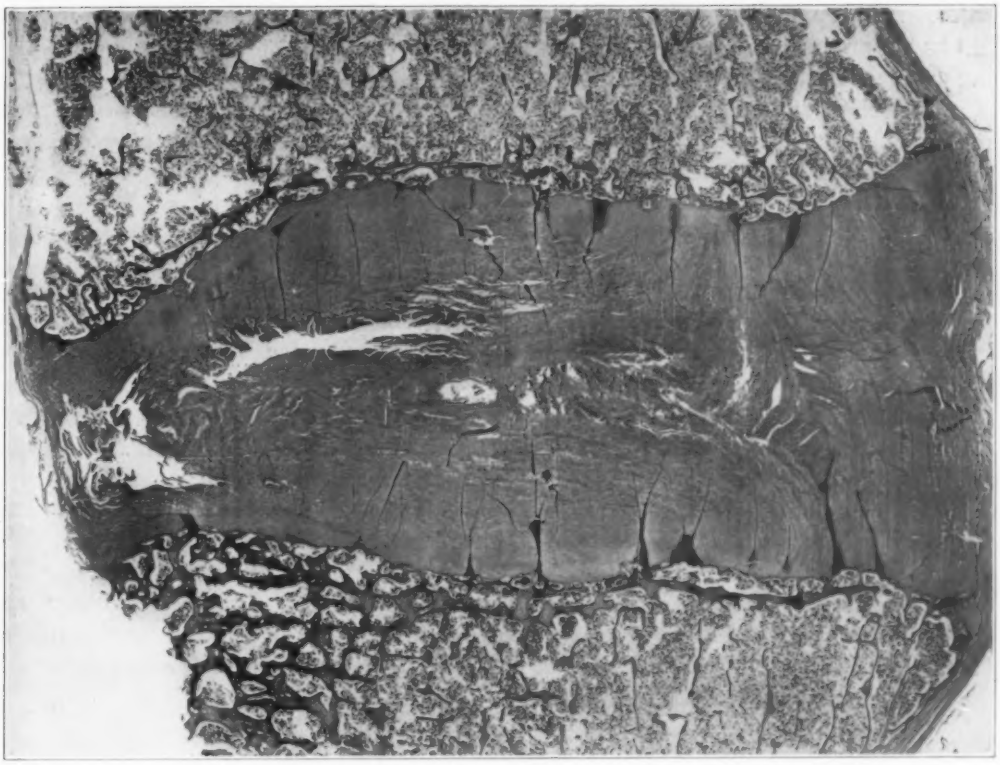

FIG. 12-A

Photomicrograph (× 3.5) showing intervertebral disc of a man, aged seventy-one years.

previously. Occasionally it is directly in the cartilaginous plate, but usually it occurs along the junction of the plate and the bone itself. This deposit appears to show the age of the disc as much as any one factor. Its amount is consistent with increasing age.

The nuclei of the cartilage cells are showing more and more pyknosis, karyorrhexis, and karyolysis. The cells tend to lose their distinct outline and stain irregularly. Fibrillation is common and there is actual necrosis in places. Several healed tears are evident.

FIG. 12-B

Roentgenogram of intervertebraldisc shown in Fig. 12-A.

B. *Annulus Fibrosus*

There is no type characteristic of this age group. Degeneration of the annulus has merely progressed. The average section viewed grossly reveals narrowing and compression of the posterior fibers of the annulus. The junction between the annulus and the nucleus is becoming less and less distinct.

The annulus appears to be broken posteriorly in a high percentage of cases in this decade. Six of the twenty-two slides show invasion of the annulus and nucleus with whorls of new, deeply staining fibrous tissue, and small blood vessels. This invasion occurs in those slides that show posterior breaking and destruction of the annulus. In a few cases the disc protrudes

posteriorly through these tears. The invasive elements must be interpreted in the same light as the protrusion into the vertebrae,—namely, an attempt on the part of the body to plug and rebuild the damaged disc tissue.

Other changes seen in this group are plaques of calcium, seen in the anterior annulus in two specimens; advanced hyalinization of the lamellae; small localized areas of necrosis; and cross and concentric tears. The lamellae are enlarged but their definite outline is less distinct and they tend to blend somewhat together.

C. *Nucleus Pulposus*

At this decade the nucleus so resembles in composition the annulus that most of the foregoing applies to it as well. The trend toward a blending of the fibrocartilaginous elements of the annulus and nucleus is progressing. The nucleus in this decade is almost completely fibrocartilage. Seen in an advanced degree, however, is the occurrence of amorphous material. This is of two types: large, coarse, localized clumps of amorphous matter; and fine strands of finely granular material, running parallel to the fibrous bundles. The larger clumps probably represent the end stage in necrosis and dehydration of the nucleus. The fine, granular material is similar to the brown degeneration and pigmentation described by Beadle, Saunders and Inman, Donohue, and others.

Large, longitudinal clefts run through many of the discs. These are seen most often where there is posterior protrusion. In these cases, the nuclear material is lost posteriorly, and the fissure remaining is the space formerly occupied by this material. In a few others the clefts are oblique, running down to nuclear protrusions that have occurred through the cartilaginous plate and into the adjacent vertebral bone.

SEVENTH DECADE

Thirteen of the twenty-seven specimens in this last group show definite evidence of disease. The changes of degeneration and trauma are rather extensive, although a few exceptions to this are seen. (One disc shows no more degenerative changes than one would expect to find in a thirty-year-old subject.) Figures 12-A and 12-B represent a disc typical of this age group.

A. *Cartilaginous Plate*

There is no specific change in the cartilaginous plate during this decade, simply a progression of the previously noted degeneration. The cartilage cells are less numerous than at earlier ages, and their nuclei are pyknotic. The cartilage matrix is pale and irregularly staining, and fibrillation has occurred in most cases. Longitudinal bands of fibrous tissue are seen in many places. Bands and small plaques of calcium are also evident, some imbedded deeply in the cartilaginous plate; most of them, however, are working up from the peripheral zone of calcification. In places the cartilage is replaced entirely by bone invading from below.

Defects are extremely frequent. In only one section in this group were microscopic protrusions not apparent. These protrusions are for the most part calcified, and in many instances they are bony in composition. Erosion of the cartilage by the marrow and bone is a very frequent picture. In fact, there are two specimens in this group that show hardly any remaining cartilaginous plate, since it has been replaced by bone from the adjacent vertebrae.

The junction between the hyaline cartilage of the plate and the fibrocartilage of the annulus is indistinct in these later years. The "streaming off" of the fibrocartilage from the cartilaginous plate is hard to see, and there is a blending of all the disc substances.

B. *Annulus Fibrosus*

The annulus in this end stage of retrogression and degeneration is in most cases still relatively intact. It is not functioning in the same capacity as in the younger groups,

in which the nucleus is semiliquid, and the annulus tends to hold in and distribute the potential forces of the nucleus. Among these older persons the stress upon the annulus is not so great as among young persons. Tears in the annulus are seen often, though most of them are old, as evidenced by the amount of repair which has taken place in the way of invasion of blood vessels and fibrous tissue. Some of the vessels penetrate well into the nucleus. They enter most commonly posteriorly, where more tears occur, but there are some examples of anterior invasion.

The fibers composing the annulus have reached a stage of advanced degeneration. They are hyalinized, torn, and in places necrotic. Strands of fine pigment can often be seen parallel to and between the lamellae. There are many groups of cartilage cells and some localized regions of calcification. In one instance, a region of new bone had developed in the posterior portion of the annulus.

C. *Nucleus Pulposus*

Even at these later years of life there is evidence of the mucoid ground substance with its included fibrillar strands, as seen in the younger specimens. Generally one is impressed, however, with the complete loss of all structure in the nucleus. Large spaces run horizontally,—evidence of desiccation. Many of the sections show nothing but masses of amorphous material where the nucleus is usually situated. Cartilage cells are very common, either in nests or diffusely scattered throughout the nucleus. In two sections bone had grown in from the adjacent vertebrae and had penetrated the nucleus pulposus. Most of the nucleus pulposus from these older patients, however, is composed of fibrocartilage.

One of the discs in this group shows enough calcium in the nucleus to be visible by roentgenographic examination. This will be discussed in a subsequent study. However, many simply show small plaques of calcium imbedded in the nucleus and visible only microscopically.

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UNCOVERTEBRAL OSTEOPHYTES AND OSTEOCHONDROSIS OF THE CERVICAL SPINE

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Neuralgic symptoms of the arms, neck, and back of the head are being referred in an increasing measure to affections of the cervical spine, the majority of which originate in the region of the intervertebral discs. Degeneration of the disc is often accompanied by loss of elasticity, eventually leading to structural changes in the adjacent vertebrae. It is in the cervical portion of the vertebral column, the site of greatest mobility, and also of greatest susceptibility to functional stress and trauma, that involvement of the discs is most common and particularly severe. Hypertrophic spondylitis or spondylosis deformans [marginal bony proliferations at the ligament attachments] is a frequent result of degenerative changes of the annulus fibrosus, the formation of osteophytes occurring as reparative manifestations. Arthrosis deformans [hypertrophic or degenerative arthritis] of the posterior articulations is a common accompaniment, the osteophytes of which may protrude into the intervertebral foramina, leading to vascular congestion and subsequent irritation of spinal roots and nerves.

The present paper deals with observations of forty patients, showing localized hypertrophic lesions, peculiar to the cervical spine and the first thoracic vertebral body, which the author terms "uncovertebral osteophytes", and which he believes may contribute to these symptoms.

ANATOMY

The full comprehension of the pathogenesis of the "uncovertebral osteophytes" is possible only if certain anatomical peculiarities of the cervical spine and the first thoracic vertebra are borne in mind. The thoracic and lumbar vertebrae have flat, smooth superior and inferior surfaces, the only exception being the upper surfaces of the first thoracic vertebra. Turner described the typical cervical vertebral body as follows: "The *body*, oblong in shape, the long axis being transverse, is small when contrasted with those of other regions. The superior surface has two well-marked lateral lips, which render it concave from side to side, while the anterior border is rounded off. The inferior surface is bevelled laterally, and thus is convex from side to side, while the anterior border is prolonged downwards to form a distinct lip. The lipped lateral margins of the superior surface rest against the bevelled edges of the inferior surface of the vertebra above, while the anterior lip of the inferior surface is in contact with the bevelled edge of the vertebra below, the thin intervertebral disc intervening in each case. The posterior surface is flat and bounds the spinal canal, while the anterior surface, also flat and rough, is situated at a slightly lower level than the posterior." The lateral lips of the superior surface of the bodies of the third to the seventh cervical vertebrae were called *processus uncinati* by Trolard, and *processus lunati* by Giraudi.

These elevations are easily seen in the anteroposterior roentgenogram of a typical cervical vertebra (Fig. 1).

Turner then proceeds to describe the pedicles of a typical cervical vertebra as "small and cylindrical, . . . directed laterally and backwards, and so arranged that the superior vertebral notch is deeper than the inferior, which, however, is broader—a result which is in part brought about by the lipped and bevelled lateral margins of the bodies which bound these notches anteriorly".

Corresponding to the anatomy outlined above, oblique roentgenograms of the cervical spine show that the anteromedial borders of the intervertebral foramina are formed, in the main, by the lateral lips of the superior surfaces of the third to the seventh cervical

vertebral bodies, by the bevelled lateral margins of the bodies above, and by only a narrow seam of the thin intervertebral disc. Lateral roentgenograms show the lateral lips posteriorly touching the dorsal surfaces of the bodies or protruding slightly beyond. The upper surface of the first thoracic vertebra also shows lateral lipping, in this respect resembling the body of a cervical vertebra. In 1858 von Luschka pointed out that in the cervical spine the discs do not extend as far laterally as the bodies themselves, and that the lateral lips of the cervical vertebral bodies form articulations with a small facet of the next higher body. He counted these articulations in the category of hemiarthroses (half joints), calling them *hemiarthroses intervertebrales laterales*, while Trolard created for them the term uncovertebral joints.

Lange and Krogdahl and Torgersen stressed the existence of some sort of lateral articulations between the vertebral bodies of the cervical spine, and they described joint-like gaps as a normal occurrence in the lateral portions of the intervertebral discs. They described the lining of the gaps as a fibrous capsule-like lateral membrane. This fibrous membrane and the lateral articulations between the individual bodies of the cervical spine could not be verified, either by Rathcke or Güntz, and the latter doubts their existence.

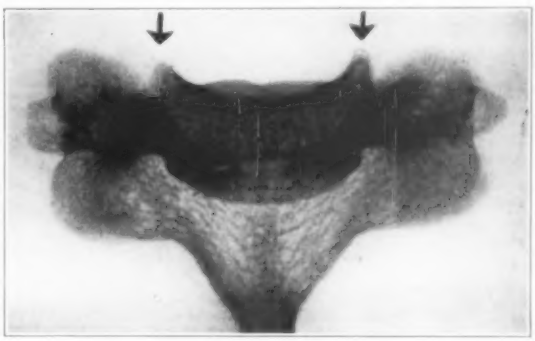

FIG. 1

Anteroposterior roentgenogram of a typical cervical vertebra, showing the lipping on the lateral upper surface.

Krogdahl and Torgersen stress the need of distinguishing between the lateral joint-like gaps and the more medially situated, irregularly outlined, inconstant gaps, which they think may be artificially produced, where no signs of degeneration are noticeable. They express doubt as to whether one is entitled to consider these lateral junctions as true articulations, since they lack a number of important features characteristic of joints. In any event, the existence of such lateral articulations between individual cervical bodies has not been demonstrated. The lateral portions of the intervertebral discs between the central and lower cervical vertebrae almost invariably contain gaps and tears, not to be mistaken for articular cavities, but not clearly set off against the rest of the disc. The system of cavities existing within the nucleus pulposus normally may be considerable. The gaps may extend from there into the annulus fibrosus or beyond, particularly posteriorly, where they may develop into the so-called recessus posterior of the cavity of the nucleus pulposus. However, it should be remembered that the tissue of the disc has no regenerative capacity. If tissue in the disc is destroyed, owing to excessive functional strain, it is not replaced as it would be in the bones, and functional adjustment does not take place. Therefore, tears and other marks of destruction occur rather frequently in the discs.

Only with these special features, characteristic of intervertebral discs, in mind, may we attempt to understand the etiology of the uncovertebral osteophytes and osteochondrosis of the cervical spine.

UNCOVERTEBRAL OSTEOPHYTES

The uncovertebral osteophytes occur at the lateral, and especially the posterolateral, lips of the superior surfaces of the third to the seventh cervical bodies. It is suggested that these osteophytes may be factors in the creation of the syndrome characterized by neuralgic symptoms of the arms, neck, and back of the head. The laterally lipped upper surface of the first thoracic vertebral body also develops exostoses, which are easily identified in the anteroposterior roentgenogram. Lange calls them spondylosis deformans of

the *hemiarthroses intervertebrales*, Krogdahl and Torgersen speak of *arthrosis deformans uncovertebralis*, and Lange and Güntz refer to them as spondylotic exostoses. These osteophytes are found at some distance laterally and posteriorly from the anterior longitudinal ligament, an important element in their etiology. Therefore, uncovertebral osteophytes cannot be considered secondary to spondylosis deformans, although they may appear in a vertebra changed by spondylosis or arthrosis deformans [degenerative arthritis]. Giraudi and Krogdahl and Torgersen maintain an etiological relationship between the bony proliferations of the uncinate processes and arthrosis deformans. As there exist no joints in connection with the uncinate processes, uncovertebral osteophytes cannot possibly be produced by the same mechanism as arthrosis deformans [degenerative arthritis]. The uncovertebral osteophytes and marginal proliferations at the lower surface of the upper vertebral body appear as a consequence of osteochondrosis of the spine [degeneration of the disc].

OSTEOCHONDROSIS OF THE CERVICAL SPINE

Osteochondrosis may run its course without causing symptoms. As we are dealing with a degenerative process, the sedimentation rate of erythrocytes remains normal. While spondylosis deformans is primarily a degenerative affection of the annulus fibrosus of the aging disc (without or with only slight involvement of the nucleus pulposus), osteochondrosis is characterized by a degenerative, destructive process of the intervertebral disc as a whole, which includes loss of structure and destruction of the nucleus pulposus. Through the effects of age and continuous stress, the intervertebral discs pass through stages of fibrillation, dehydration, and fissuring; the adjacent vertebral bodies undergo subchondral osteosclerosis, marginal proliferation, and decrease in height. The destruction of the discs may assume such proportions that the bodies rub against each other. One of the sequelae of the degeneration of discs as a whole is the marginal bony proliferation of the lateral lips of the cervical bodies and of the lower surface of the body above.

CLINICAL ASPECTS

Forty cases are briefly reviewed. Except for three, all patients were over forty-five years of age. Twenty-two were men. Special emphasis was not given to persons engaged in laborious occupations, nor to those whose work involved any special movements of the cervical spine, such as watchmakers or precision-machine operators. Most of the patients complained of boring brachial pain, radiating down one or both arms, with a tingling sensation in the fingers, and pain in the shoulders and the back of the head. Sensitivity to cold and pain was particularly marked at night, so that sleep was often disturbed. Many patients complained of dizziness, headache, earache, dysphonia, and transitory swelling of one hand or forearm. Muscle strength was impaired, but distinct sensory symptoms were rarely noted. One or both occipital nerves were invariably sensitive to pressure, as were the cervical and brachial plexus and the trapezius on one or both sides.

ROENTGENOGRAPHIC FINDINGS

The most striking effects were observed in the roentgenograms. The anteroposterior view showed reduced height of one or several of the vertebral bodies from the fourth to the seventh cervical inclusive, as well as of the corresponding intervertebral spaces. Also evident were atrophy, bony lipping of one or several uncovertebral osteophytes, and marginal proliferations at the lower surface of the body above the one affected.

An oblique roentgenogram showed uncovertebral osteophytes and marginal proliferations of the inferior surface of the vertebral body above. One or more of the intervertebral foramina were often narrowed. There were occasional exostoses in the foramina between the seventh cervical and the first thoracic vertebrae. Uncovertebral osteophytes were found with particular frequency in the sixth cervical vertebra.

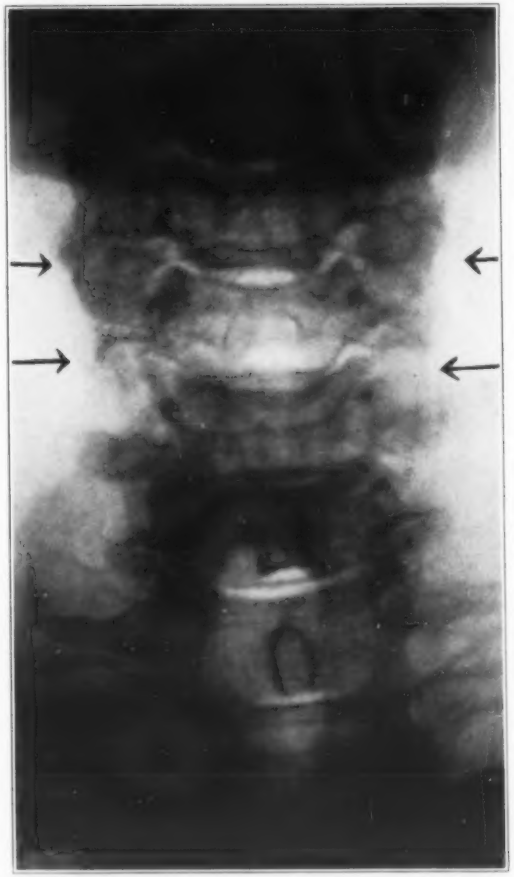

FIG. 2-A

E. S. Anteroposterior roentgenogram of a patient sixty-one years old, showing uncovertebral osteophytes of the fifth and sixth cervical vertebral bodies and marginal proliferations of the inferior surface of the fifth cervical body.

FIG. 2-B

Lateral roentgenogram of the same patient, showing spondylotic osteophytes of the anterior edges of the fifth, sixth, and seventh cervical vertebral bodies, and narrowing of intervertebral joints.

FIG. 2-C

Oblique roentgenogram of the same patient, showing uncovertebral osteophytes projecting into the intervertebral foramina between the sixth and seventh cervical vertebrae and between the seventh cervical and the first thoracic vertebrae.

In the lateral view, spondylotic osteophytes were seen at the anterior edges of the bodies of several of the cervical vertebrae. Posterolateral uncovertebral osteophytes occasionally projected slightly beyond the bodies, appearing to be intraspinal, but actually were within the foramina.

CASE REPORT

E. S., a merchant, sixty-one years old, reported that five years before he had suffered for some months from neuritis of both arms. During the past four weeks there had been weakness and numbness of the left arm, and a tingling sensation down to the finger tips. The symptoms were more pronounced at night and were markedly influenced by cold. The cervical spine was tender to pressure. Active and passive movements in the shoulder joint were normal. The left brachial plexus was sensitive to pressure. No sensory or motor disturbances of any significance were noted in the arms, apart from considerable awkwardness in performing more delicate movements. On the left, the trapezius was tender. The sedimentation rate was normal.

The anteroposterior roentgenogram (Fig. 2-A) showed bony atrophy of the bodies of the cervical vertebrae, particularly of the fifth. Lumpy uncovertebral osteophytes were seen on both sides of the sixth cervical body, and marginal proliferations at the lower surface of the fifth. There was thickening of the uncovertebral processes on both sides of the fifth cervical body.

The left lateral roentgenogram (Fig. 2-B) showed loss of the normal curvature of the cervical spine. Spondylotic osteophytes were seen at the anterior edges of the fifth, sixth, and seventh cervical vertebrae. There was narrowing of the posterior articulations.

The left oblique view (Fig. 2-C) showed osteophytes at the lateral lips of the seventh cervical and first thoracic vertebral bodies, protruding into the intervertebral foramina between the sixth and seventh cervical, and between the seventh cervical and first thoracic vertebrae.

The diagnosis was spondylosis and arthrosis deformans with uncovertebral osteophytes.

DISCUSSION

In the case illustrated the presence of uncovertebral osteophytes and exostoses at the lower bevelled surfaces of the vertebral body suggests a primarily degenerative lesion of the underlying narrow intervertebral disc. Krogdahl and Torgersen reported occurrence of rather large exostoses in conjunction with osteochondrosis [degeneration of the disc], exclusively "at the edges of the uncovertebral joints". From this they conclude that the pathogenesis of these exostoses must necessarily be different from that established for osteophytes arising on the basis of marginal bony proliferation at ligament attachments. With this the author agrees. However, it should be borne in mind that arthrotic exostoses of the posterior articulations may be co-existent with osteophyte formation on the basis of osteochondrosis.

Characteristic of osteochondrosis of the cervical spine is the abnormal posture and reduced mobility of that part. Resulting abnormal mechanical conditions reduce the normal lordosis, and may occasionally lead to kyphosis. The majority of symptoms are caused by the excessive strain imposed on muscles and ligaments. Narrowing of the intervertebral foramina is caused by ingrowth of the uncovertebral osteophytes, which may result in pressure on vessels and nerve roots at this site. These spicules are seen in oblique roentgenograms. The writer agrees with Giraudi that uncovertebral exostoses are more frequently the cause of nerve symptoms than are exostoses arising from the small posterior articulations as a result of arthrosis deformans.

According to Krogdahl and Torgersen, the more anteriorly situated osteophytes of the uncinate processes may project into the canal of the vertebral artery, affecting the contained sympathetic fibers and the artery. These uncovertebral osteophytes, appearing in anteroposterior roentgenograms, are the cause of the cervical posterior sympathetic syndrome of Barré, consisting of headache, pressure behind the eyes, dizziness, tinnitus, earache, and dysphonia. Damage to the spinal cord from posterolateral uncovertebral osteophytes has not been observed.

THERAPY

In the treatment of osteochondrosis, much benefit is derived from the use of moist

heat or simple cotton bandages applied on the cervical spine. Antineuralgics or other analgesics are indispensable. The patient should be advised to rest his neck on a soft roll at night. In severe cases, injections of large doses of procaine solution into the affected plexus are occasionally successful. However, it is true that 10 per cent. of our cases did not yield to therapeutic measures. One patient, with considerable narrowing of several intervertebral foramina and with several exostoses probably projecting into the right canal of the vertebral artery, did not show improvement even after two years of treatment.

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THE RESULTS OF EPIPHYSEODESIS AND FEMORAL SHORTENING IN RELATION TO EQUALIZATION OF LIMB LENGTH*†

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FOLLOW-UP STUDIES

Many methods have been proposed for the equalization of length of the lower extremities. Most of these were of little more than theoretical value, because results were either too slight or too uncertain. Others presented complications which have made them unpopular. Into this group fall bone-lengthening operations, and possibly growth arrest by irradiation. Two methods have been more generally accepted, because of their relative simplicity and apparent effectiveness. They are (1) epiphyseodesis (epiphyseodiaphysial fusion) and (2) bone shortening,—principally femoral shortening.

It is our purpose in this study to evaluate the results of these two operations as observed in a series of cases treated at the Hospital for Special Surgery.

I. Epiphyseodesis

The technique of epiphyseodiaphysial arrest used in this series is that described by Phemister in 1933, with the exception that in most cases we tried to curette more of the epiphyseal cartilage. In addition, the remaining portion of the epiphyseal plate was thoroughly cauterized with electrocautery. Weight-bearing without mechanical aids was generally allowed at the end of three weeks. Immobilization in plaster-of-Paris was employed in only three of the four more recent cases.

Method of Determining Age and Extent of Proposed Epiphyseal Fusion

The proper timing of the operation with respect to the patient's age, and the estimation of the expected growth of the two limbs, and of the discrepancy that will result, constitute the most difficult and probably the most inaccurate part of the whole procedure. The method used here has been previously described by two of us [4]. It is based on the estimated percentage of limb length that is contributed by the growth from the upper tibial epiphysis (25 to 30 per cent.) and of the lower femoral epiphysis (30 to 35 per cent.). The formula for calculation is:

$$\frac{\textit{Expected Discrepancy}}{\textit{Expected Growth}} \textit{ equals the percentage of growth to be eliminated.}$$

The estimation of expected growth is usually based upon the measurement of the father's or the mother's limb length, depending upon the child's sex. This is not an infallible guide, and it is generally true that today most children are taller than their parents. If we err in our predictions, it is likely to be because we underestimate rather than overestimate the amount. We also take into consideration the height of the child in relation to the average height of children of the same age, and any information we may be able to obtain of the parents' height at the same age.

For example, let us take a boy of twelve years of age with a postpoliomyelitic involvement of one leg, but able to get about actively without a brace. The limb length on the normal side is thirty inches and on the involved side twenty-eight inches. The boy is of

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average height for his age; his father's height is seventy inches and his limb length thirty-six inches. Our prediction of expected growth is six inches and our formula is as follows:

$$\frac{(\textit{Expected Discrepancy})\ \textit{2 inches}}{(\textit{Expected Growth})\quad \textit{6 inches}} \textit{ equals 33 per cent.}$$

In other words, we should eliminate 33 per cent. of the expected growth, which corresponds approximately to what we may expect from the lower femoral epiphysis, and we would perform an epiphyseodiaphysial fusion. If we fused the upper tibial epiphysis, we would obtain too little correction, and if we fused both the lower femoral and upper tibial epiphyses, we would obtain too much correction (55 to 65 per cent.).

This method of prediction is not entirely accurate; perhaps no method is. We have had no experience with the method of Abbott and Gill. As will be seen, there are many individual variations in bone growth, and factors of sex and age of attaining sexual maturity may also be important.

Method of Measurement

The measurements of limb length upon which the study is based were made by use of a tape, measuring from the anterior superior spine of the ilium to the medial malleolus, checked by trial of different elevations of known height under the short limb in the standing position. While we realize the variation of measurements by different surgeons making use of the same bony landmarks, we believe that there will be little variation in the net difference between the length of the legs, which is of chief importance. We experimented with roentgenographic measurements of both limbs, made on double-length

TABLE I

CONDITIONS CAUSING DISCREPANCY IN LEG LENGTH

Condition	No. of Cases	Condition	No. of Cases
Poliomyelitis	68	Congenital deformities	2
Epiphyseal injury	1	Congenital coxa vara	2
Compound fracture	1	Congenital pseudarthrosis	3
Tuberculosis of hip	1	Congenital dislocation of hip	2
Osteomyelitis	2	Congenital shortening	1
Hemangioma	1	Spina bifida	1
Osteitis fibrosa cystica	2	Spastic hemiplegia	1
Liposarcoma	1		
		Total	89

TABLE II

ANALYSIS OF OPERATIONS

Etiology	No. of Cases	Type of Epiphyseodesis			Total Operations
		Femoral	Tibial, Fibular	All Epiphyses	
Poliomyelitis	68	24	40	15	79
Other etiology	21	5	8	11	24
Totals	89	29	48	26	103

TABLE III

CLINICAL EVALUATION

Results	Cases	Per cent.
Good results (discrepancy of 2 centimeters or less of anticipated gain)	40	49.4
Mediocre (some incomplete)	21	25.9
Poor (discrepancy of over 3 centimeters or gain not realized)	20	24.7
No clinical data	8	

films with a metal rule strapped to one thigh to serve as an index to the amount of magnification or diminution, but concluded that the margin of error was unimportant. In cases of pelvic asymmetry, even roentgenographic measurements may be inaccurate, and in such cases the best method is that of trying elevations of different height under the foot.

Review of Cases

From 1935 to January 1942, 103 epiphyseodesis operations were performed on eighty-nine patients at the Hospital for Special Surgery. In sixty-eight cases the etiological factor in the discrepancy of limb lengths was poliomyelitis. In twenty-one cases other etiological factors were responsible (Table I). (This latter group are hereafter referred to as non-paralytic cases.) It will be noted in Table II that in twenty-nine cases the femoral, and in forty-eight cases the upper tibial and fibular epiphyses alone were fused. In twenty-six cases all the epiphyses about the knee were fused in one stage, representing 22 per cent. of the poliomyelitic cases and 52.4 per cent. of the non-paralytic cases. This difference indicates that the actual or expected discrepancy was generally greater in the latter group. In thirteen of the cases all epiphyses were closed, but in two operations at different times. In these cases there was generally uncertainty as to the expected discrepancy, and the second operation became necessary when the first proved inadequate. This occurred in ten instances in the poliomyelitic group, while it happened in only three cases in the non-paralytic group (Table II).

The age at time of operation ranged from six years to fifteen years; there being only one patient of six, none of seven, and seven of eight years of age. The largest groups were in the ninth, tenth, and eleventh years.

The period of follow-up extends from one to eight years, averaging three and two-tenths years.

EVALUATION OF RESULTS

Evaluation of epiphyseodesis in this series was open to the following sources of error:

1. Lengths of extremities determined by clinical measurement were used as a check on the operation, and of necessity were frequently made by different clinicians with variable results. Roentgenographic measurement was used in some cases, but this seemed to offer no real advantage.

2. In many cases the operation was performed to arrest or to retard an increasing discrepancy, rather than to gain true equalization of limb length. Follow-up measurements may show no correction of discrepancy, and yet the result may well be considered good. This is especially true in the non-paralytic series.

3. Occasionally operations were performed following epiphyseodesis for the purpose of increasing joint stability or correcting deformity, and these operations may have altered limb lengths, or affected the accuracy of mensuration to some extent.

There are two methods of evaluating the results. The first is to consider them from the standpoint of a final discrepancy of two centimeters or less, which can be easily cor-

TABLE IV

ANALYSIS OF RESULTS OF OPERATIONS

Results	Poliomyelitis	Other Etiology	Average Age, Female	Average Age, Male	All Epiphyses	Tibial and Fibular	Femoral	Totals
Good results (75 per cent. correction or better)	15	3	10.2	10.8	8	7	3	18 (22.7 per cent.)
Mediocre or incomplete (25 to 75 per cent. correction)	24	8						32 (40.5 per cent.)
Poor (25 per cent. or less correction)	17	4	11	13.6	9	6	6	21 (26.5 per cent.)
Deformity requiring operative correction	8							8 (10.1 per cent.)
Slight deformity, no correction required	7							7
Total deformities								15 (16.8 per cent.)
Not sufficient data or complicated by other factors								10

rected by a small shoe elevation. In general, so slight a discrepancy may be considered a good result. Included in this group are those cases in which the purpose of surgery was merely to prevent an increase in discrepancy, when the anticipated result was obtained. This then is a *clinical evaluation.*

The second method is to use the percentage of discrepancy attained as a basis of evaluation. This permits a mathematical estimation of the perfection of the operation and of the accuracy of the method of prediction, but does not necessarily reflect the actual clinical result. In this method we have arbitrarily considered a correction of discrepancy of 75 per cent. or better as a good result, while 25 per cent. or lower is graded as poor. Corrections which fall between 25 per cent. and 75 per cent. are considered mediocre, or in some cases incomplete results.

Though not precisely true, we have considered growth of the extremities complete at fourteen years in females and at sixteen in males. According to this standard, eighteen of the eighty-nine patients were still growing at the time of evaluation, and the results may be considered still incomplete.

FIG. 1-A FIG. 1-B

Case A.Y. Illustrating deformity of medial condyle of tibia following epiphyseal arrest. Fig. 1-A: November 6, 1939; Fig. 1-B: March 1, 1943.

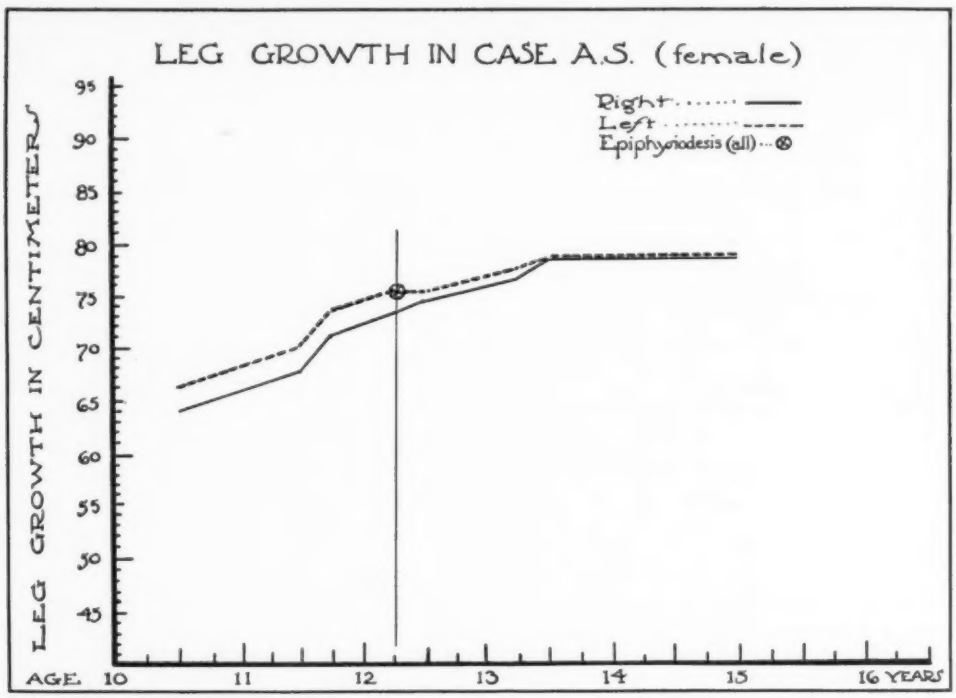

FIG. 2

Evaluation by First Method (Clinical impression)

Employing the first method—namely, a final discrepancy of two centimeters or less plus the cases in which an anticipated goal was attained—forty cases or approximately 50 per cent. came within the desired result. Ten were in the non-paralytic group. By sexes, the group was evenly divided. Of the thirty poliomyelitis cases here included, only one had so slight a discrepancy as two centimeters preoperatively. In eight cases observations were insufficient. Percentages in this method are, therefore, based on a total of eighty-one cases (Table III). While considering clinical results, it would be wise to discuss the deformities of growth resulting from operation and requiring operative correction.

Deformities resulting from unequal arrest of growth of all parts of the epiphysis constitute a serious hazard, especially in elective surgery (Fig. 1). The deformities usually developed within one year following operation. Those so severe as to warrant further corrective surgery were classed as poor clinical results, even though the final result may have been good. In eight cases, or 10.1 per cent. of the series, the deformities were severe enough to require corrective operations. In another seven cases, deformities were noted, but they were not severe enough to require operative correction, and did not affect the final result. They do, however, emphasize the risk of this complication. Therefore, a total of 16.8 per cent. of this group of patients showed some deformity resulting from epiphyseodesis. Of these, seven patients showed valgus; and six patients, varus deformities. In one case the type of deformity was not recorded. In the remaining case, a severe double deformity developed, with varus of the lower femoral and valgus of the upper tibial epiphyses.

We believe that most of these deformities of growth resulted from faulty operative technique, especially in the preparation and placing of the bone grafts. The facts that most of these cases did not have plaster-of-Paris immobilization, and that early weight-bearing was permitted may have been contributory factors. In only one case was excessive correction obtained. This patient was a boy with poliomyelitis, who had had the

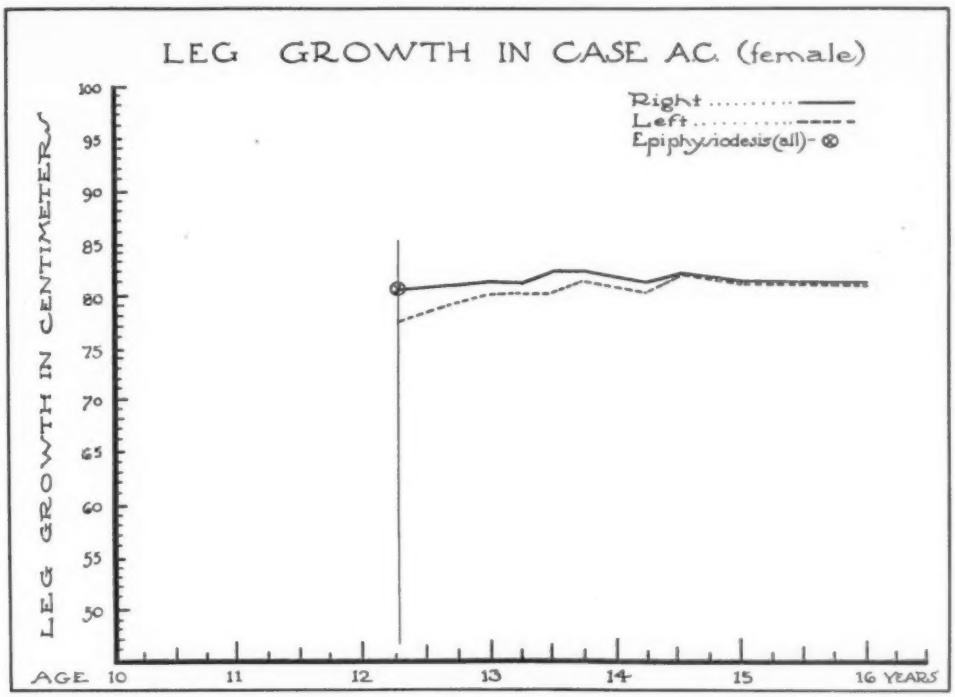

FIG. 3

upper tibial and fibular epiphyses fused at the age of eleven years when the discrepancy was 1.5 centimeters. At the age of fifteen years the length of the short leg exceeded that of the leg operated upon by one centimeter, but this difference was well within the range of a good result.

Evaluation by Second Method (Percentage of correction of discrepancy attained)

This stricter method, as was said before, reflects more the accuracy of the method of prediction than the success of the result from a clinical standpoint. Eighteen cases, or 22.7 per cent. of the series, were rated as good results, — that is, they obtained a correction of 75 per cent. or better of their preoperative discrepancy (Table IV).

Insufficient correction of discrepancy as seen in Table IV was obtained in twenty-one, or 26.5 per cent., of the cases. Of this group, sixteen, or 76 per cent., were female, and five were male.

It was noted in most of this group of cases that either the operation was done too late, or too little was done. Epiphyseodesis after eleven years in the female and after twelve to twelve and a half years in the male is of questionable value. In this group of poor results, seven females were over eleven years; three males were over twelve years. Of these ten cases, total epiphyseodesis was done in seven.

While this rule applies for the great majority of cases, there are marked individual variations in both directions. This is illustrated by the following cases:

CASE 1. A. S., a girl, twelve years old, had had poliomyelitis. All epiphyses were closed at twelve years and four months. When thirteen years, seven months old, she had gained 2.5 centimeters and limb lengths were equal.

Little or no correction should have been expected at this age, but equalization was obtained (Fig. 2).

CASE 2. A. C., a girl of twelve years, had suffered from osteitis fibrosa cystica. She had all epiphyses closed at twelve years, but within two years she had completely overcome a discrepancy of 3.1 centimeters (Fig. 3).

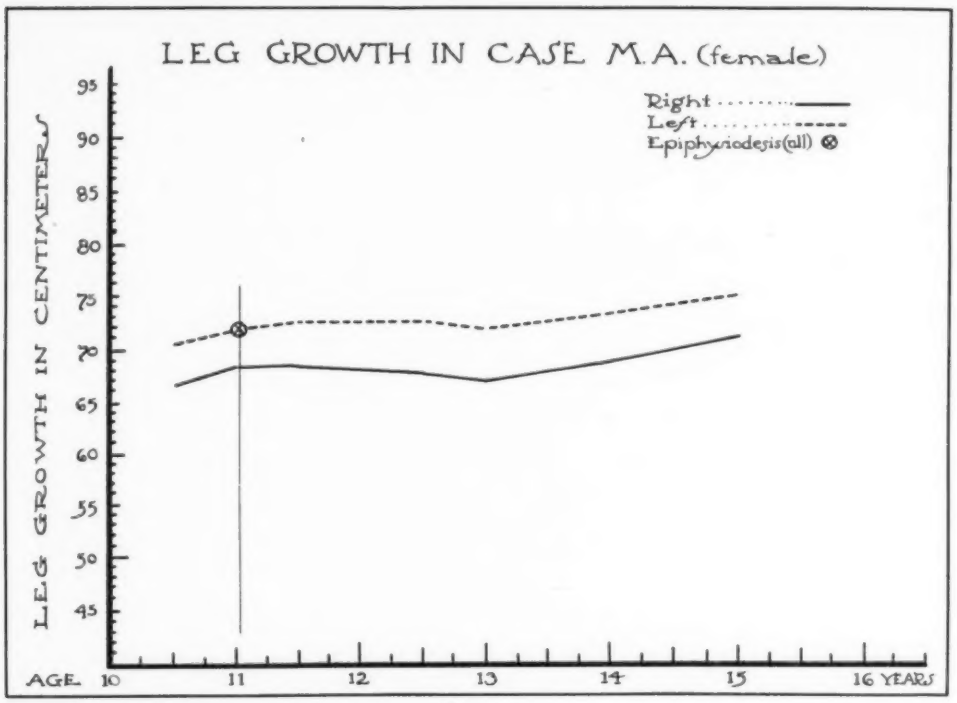

FIG. 4

These two cases represent marked variations from the average in a desirable direction. However, the opposite more frequently seemed to occur.

CASE 3. **M. A.** was a poliomyelitic case. The girl had all epiphyses about the knee closed at eleven

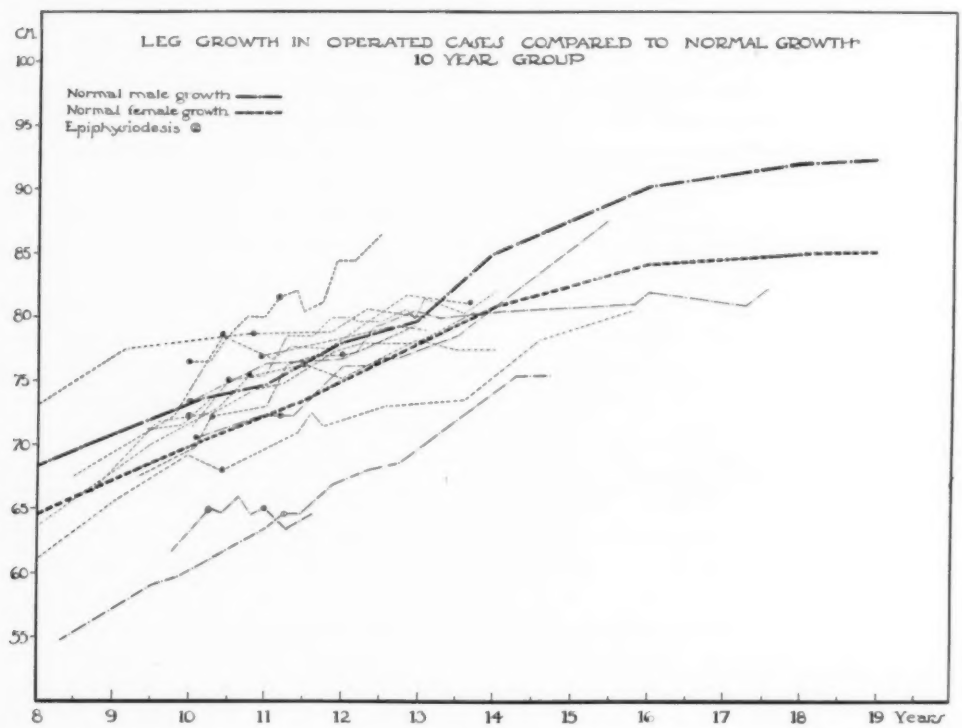

FIG. 5 (Table V)

years. At fourteen her discrepancy remained the same, and her limb lengths had not increased perceptibly. She was short and of a Mediterranean race (Fig. 4).

There were a number in the group who conformed to this general picture, and in whom failure was encountered. This would lead to the conclusion that race might be an important factor. An analysis of the poor results, however, revealed that the group was almost evenly divided between Nordic and Mediterranean types. However, the female patients mentioned above were of a physical type that attains secondary sex characteristics early, and it was our personal observation that usually little growth could be expected in these individuals. These cases, then, together with others previously mentioned in which good results were obtained, serve to illustrate variations in growth, which make the usual methods of prediction inadequate. The extent of these variations can best be illustrated by the following analyses:

Group I

Females, twelve or thirteen years of age at operation.
(Ten were poliomyelitic cases and six were non-paralytic.)
Five made no gain.
Four gained approximately 25 per cent.
Two gained approximately 50 per cent.
Two gained approximately 100 per cent.
In three cases, no follow-up data were available.

Group II

Males, thirteen or fourteen years of age at operation.
(Seven were poliomyelitic cases and four were non-paralytic.)
Two made no gain.
Two gained approximately 25 per cent.
Four gained approximately 50 per cent.
One gained approximately 100 per cent. (lower femoral).
In two cases no follow-up data were available.

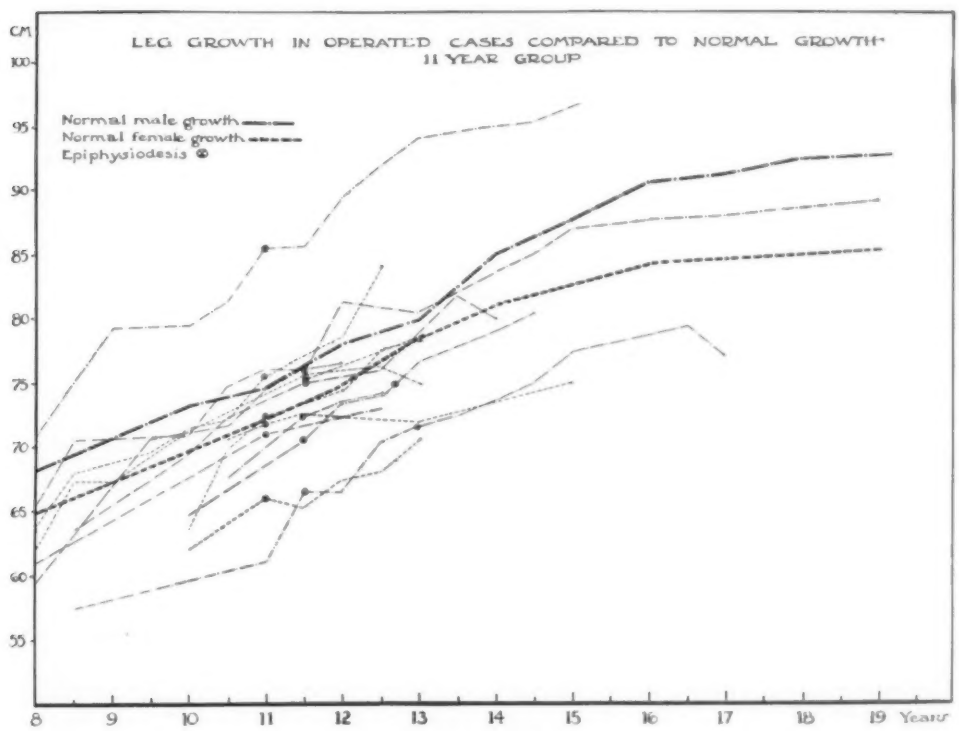

FIG. 6 (Table VI)

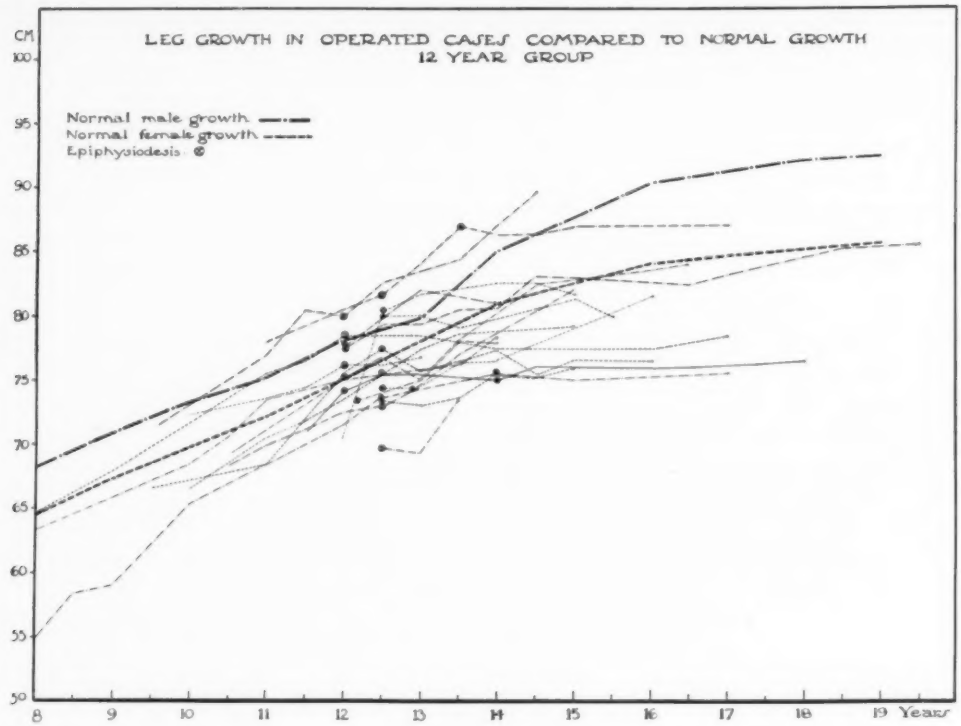

FIG. 7 (Table VII)

Of these cases in Group II, the two that showed no gain had all epiphyses closed; while in the one perfect case only the lower femoral epiphysis was operated upon.

One of the most interesting cases in the series was the following:

CASE 4. E. B., a girl, eight years old, was first seen in the Out-Patient Department on August 15, 1934, with an extensive deep hemangioma of the left leg. She was referred to another hospital for treatment by

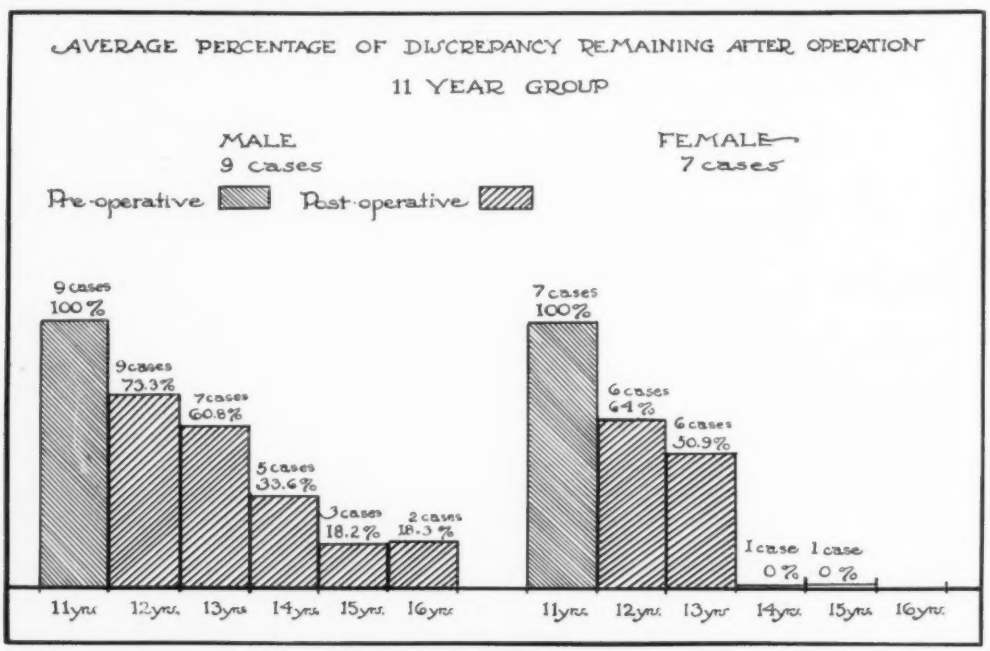

FIG. 8 (Table VIII)

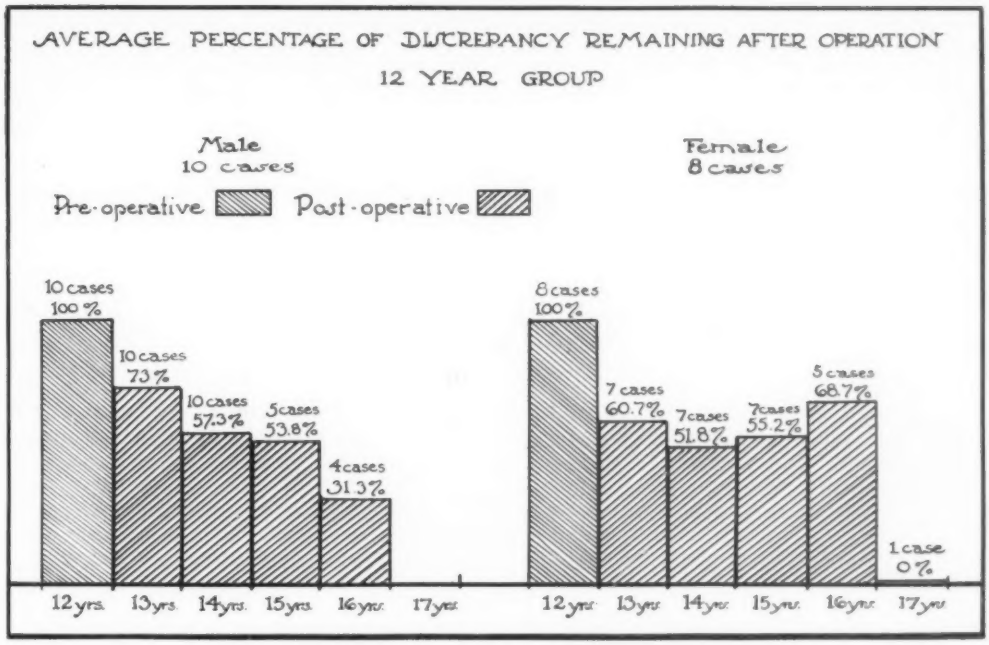

FIG. 9 (Table IX)

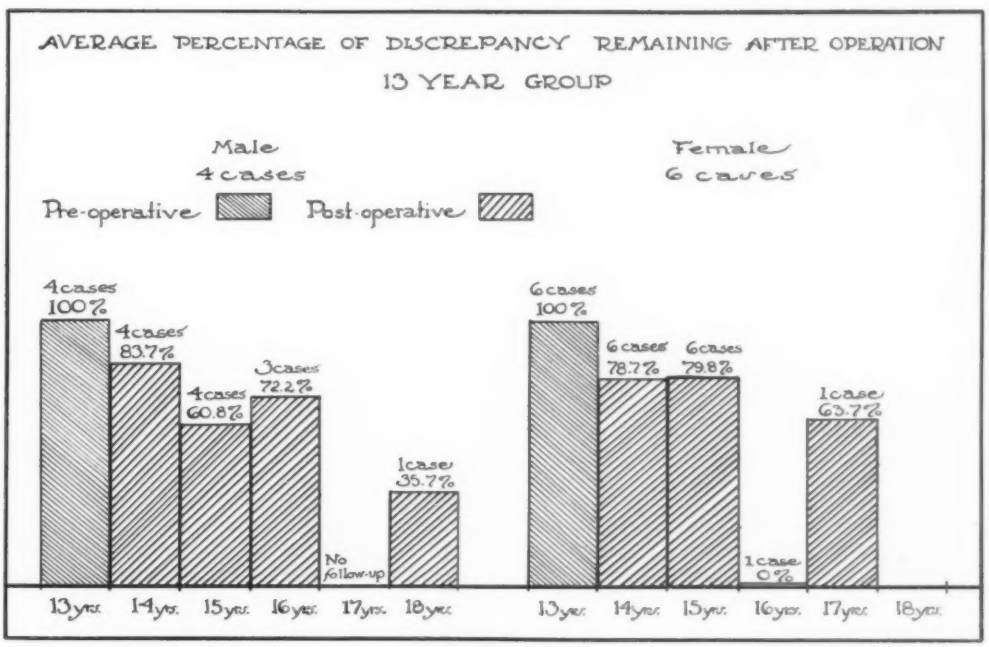

FIG. 10 (Table X)

irradiation. The recorded limb lengths were: right, 65.2 centimeters (24.4 inches); left, 67.5 centimeters (27 inches). She was given x-ray irradiation to all the epiphyses of the left tibia as this was the area of lengthening. Treatments were carried out through 1935 and 1936. In 1937 both limbs were recorded as equal in length at 76.5 centimeters (30.6 inches). The child was then eleven. In January 1939, it was noted that the length of the right leg exceeded that of the left by 2 centimeters. It was found that in the two previous years the patient had grown 9.5 centimeters on the right and only 7.5 centimeters on the left. Even though the patient was then thirteen years old, on April 12, 1939, a total epiphyseodesis was done on the right knee. The following measurements recorded on September 9, 1940, show that a good result was obtained:

Preoperative length—Right: 84 centimeters (33.6 inches); Left: 81.5 centimeters (32.6 inches).

Postoperative length—Right: 85 centimeters (34 inches); Left: 84.2 centimeters (33.7 inches).

II. Femoral Shortening

Since January 1938, nineteen shortening operations have been performed. Eighteen of these were shortening of the femur; there was one shortening of tibia and fibula. In nine cases the cause of the discrepancy was poliomyelitis; in four cases osteomyelitis; single cases were caused by fibrous dysplasia of bone, congenital shortening, slipped femoral capital epiphysis, tuberculosis of the hip, osteochondritis juvenilis, and congenital dislocation of the hip. Nine were males; ten females. Two of the males had had previous epiphyseodeses, one at thirteen years and six months, the other at fourteen years. One female had had an epiphyseodesis at thirteen years without benefit.

The technique of the femoral operation was a long oblique osteotomy, done in every case through Henry's anterior incision, with overlapping of the bone ends (Fig. 11). In the first case (D. E.) internal fixation was obtained by Steinmann pins transfixing the fragments, and kangaroo tendon. In all other cases, internal fixation was secured by the use of several vitallium screws fastening the fragments together. External fixation, usually a plaster spica, was used in all cases for eight weeks. Weight-bearing was generally permitted at twelve weeks.

Fig. 11
Case R.C., July 1, 1942.

The age range at time of operation was thirteen and a half years to forty-two years. The follow-up period was from six years to twelve weeks.

The average correction obtained at operation was 4.7 centimeters (1⅞ inches). The greatest correction obtained was 5.7 centimeters (2¼ inches); the least 3.5 centimeters (1⅜ inches).

There were no non-unions or malunions. There were complications in three cases (15.7 per cent.), but in all cases the final result was satisfactory.

1. C. L., female, nineteen and a half years old, had suffered from osteomyelitis of both hips, with resulting femoral shortening of 4.5 centimeters (1¾ inches). A postoperative wound infection with draining sinuses developed, and one year later it was necessary to remove vitallium screws and excise the sinus. This resulted in healing, and correction was maintained. This infection might have been anticipated, since both femora had been involved in the osteomyelitis.

2. B. C., male, fourteen years old, had probably suffered atypical fibrous dysplasia of bone, although the diagnosis was uncertain. Shortening of 5.7 centimeters (2¼ inches) of the left femur (the good limb) was performed on December 15, 1943. Postoperatively, the temperature rose to 101 degrees. There was continuous slight serous, non-purulent discharge from the wound. The cultures showed bacillus subtilis and staphylococcus albus. On February 5, 1944, the operative wound was opened widely, but abscess or deep infection was not found. The draining sinus continued until March 1, 1944. The boy was discharged well on March 10, 1944, and had no further trouble.

3. G. Mc., female, forty years old, had congenital dislocation of the right hip. Shortening of 5.7 centimeters (2¼ inches) of the left femur was done on July 6, 1943. The patient was unable to overcome the stiffness of the left knee after the plaster was removed. The pointed spike of the proximal fragment of the femur penetrated near to the suprapatellar pouch, and a calcified hematoma formed in this area, which required surgical excision on April 13, 1944. The patient recovered flexion to an angle of 70 degrees (Figs. 12-A, 12-B, and 12-C).

SUMMARY

I. *Epiphyseodesis:*

1. From the standpoint of the percentage of correction of the original discrepancy of limb length, only 20.7 per cent. of the results were classed as excellent (75 per cent. or more correction), and 23.1 per cent. of the results were poor (25 per cent. or less correction). This is chiefly a reflection on the timing of the operation and the selection of the epiphyses to be fused.

2. From the clinical standpoint, satisfactory results (final discrepancy of 2 centimeters or less) were obtained in 50 per cent. of the cases.

3. While, on the basis of our results, it is generally a mistake to perform epiphyseodesis for the correction of shortening in a female after the age of eleven years, and in a male after twelve and a half years, there were cases in our series which demonstrated that this is not always true. These exceptional cases tended to prove the inaccuracy of any method of predicting bone growth.

4. The development of bone deformities from unequal arrest of epiphyseal growth following operation was found in 20.7 per cent. of the cases. In eight cases, or 9.7 per cent., these deformities were too slight to affect the final result. They serve to emphasize the risk of the operation and the necessity for thorough fusion of the epiphyses.

II. *Femoral Shortening:*

1. Shortening of the femur by a simple, satisfactory technique was performed in nineteen cases, with ages ranging from thirteen and a half to forty-two years.

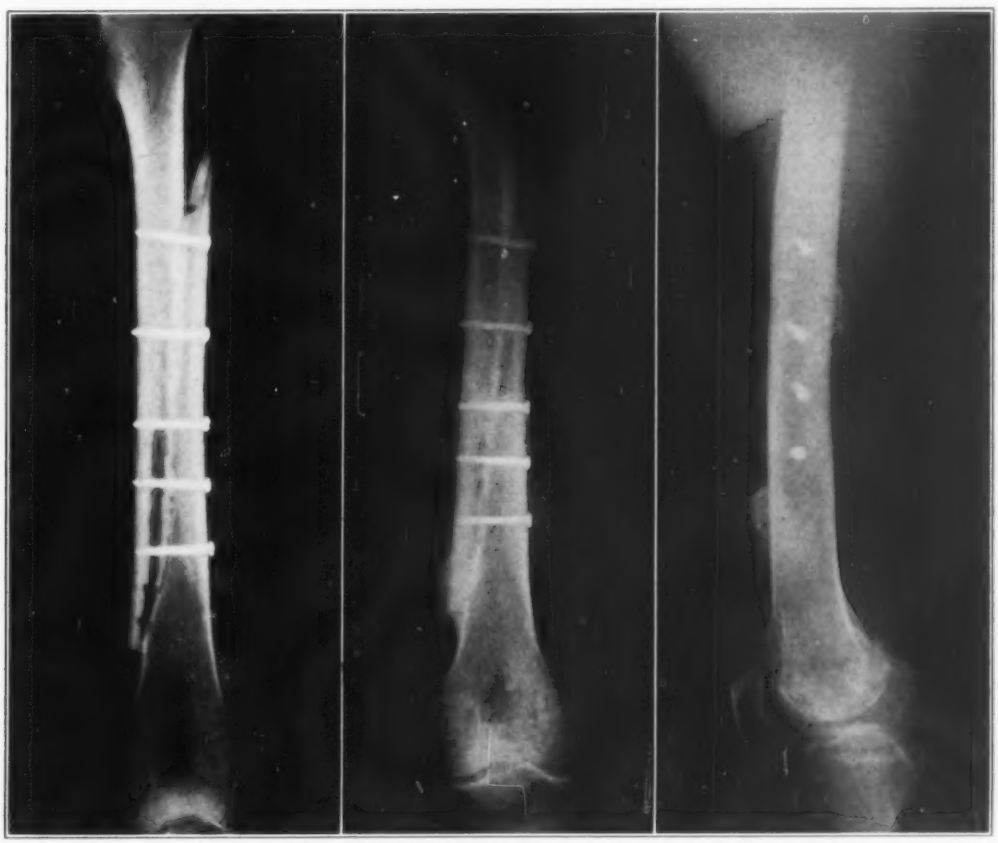

FIG. 12-A
Case G. Mc.: September 1, 1943.

FIG. 12-B
February 7, 1944.

FIG. 12-C
February 7, 1944.

2. The average correction obtained in this group was 4.7 centimeters (1⅞ inches). There were no instances of delayed union, malunion, or non-union.

3. Complications occurred in three cases. Two patients had postoperative infections, one transient and the other requiring secondary surgery. Both cleared up with final good results. The third was a localized calcifying hematoma, causing limitation of knee flexion. A good result was obtained, following excision of the calcified mass.

CONCLUSIONS

1. The problem of equalization of limb lengths is a complicated one. No one procedure will provide the solution for all cases. Each case must be carefully studied, and surgery should not be undertaken without consideration of the risk involved. Epiphyseodesis, while apparently a simple and mild surgical undertaking, is irreversible and presents certain dangers which must be weighed in the balance. The possibility of severe growth deformity is the most important of these, and illustrates the need for meticulous and thorough technique during surgery itself. We also feel that, following operation, the healing epiphysis should be protected for a longer period than we have used.

2. In the selection of cases and of age for operation, the method used has proved satisfactory, but is nonetheless still inaccurate in some cases. The development of accurate methods for exact prediction of bone age is needed. Race does not seem an important factor in growth prediction, but early sexual maturity, especially in girls, is a probable contra-indication to epiphyseodesis. Operation after the age of eleven in girls and twelve and a half in boys will avail but little in the average case. There were certain cases in this series, however, where splendid results were obtained later, usually in that group in which the development of secondary sex characteristics was delayed.

3. The operation is of particular value in young patients where the discrepancy is increasing rapidly, and a considerable difference in the length of the two extremities would be normally expected. In such cases, epiphyseodesis alone may suffice, or a femoral-shortening operation may be done later.

4. The use of epiphyseodesis is, of course, restricted to those still growing.

5. Femoral shortening is an exact procedure with a definitely predictable result. It is the only operation useful when growth has been completed. It presents a relatively simple surgical problem with a smaller percentage of complications than from epiphyseodesis. Its primary limitation is the maximum correction obtainable, about three inches.

6. The disadvantage of both epiphyseodesis and femoral shortening is the reduction of total height of the individual, which in persons of short stature is not desirable.

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Note: Discussion of this paper was included in the January issue of *The Journal* (See page 33).

CLOSED MANIPULATION FOR THE REDUCTION OF FRACTURES OF THE NECK OF THE RADIUS IN CHILDREN

BY RAPHAEL R. GOLDENBERG, M.D., F.A.C.S., PATERSON, NEW JERSEY

In the treatment of fractures of the neck of the radius in children, where the displacement is marked, many authorities[1,2,3,6,7] believe that only two methods are likely to give satisfactory results,—either excision of the capital fragment or open reduction. Sutro found that excision of the radial head may lead to overgrowth of the shaft of the radius. In the writer's experience, overgrowth of the radial shaft occurred in several instances and caused subsequent limitation of elbow motion.

In 1934, Patterson introduced a simple and effective manipulative technique for the reduction of fractures of the neck of the radius in children. The Patterson manipulation is performed with the elbow extended and the forearm supinated, an assistant exerting strong proximal traction on the arm. When the patient's left elbow is affected, the surgeon's right hand grasps the patient's left forearm just proximal to the wrist joint, and maintains strong distal traction on the supinated forearm. The surgeon's left hand is placed about the patient's medial humeral condyle, and firm lateral pressure is exerted. Then the forearm is slowly forced medially until the carrying angle is reversed, thus opening the lateral joint space. If the fragment is displaced posteriorly, the surgeon's left index and middle fingers are used to replace the fragment. If the fragment is displaced anteriorly, then the surgeon's left thumb is used for replacement of the radial head.

These fractures usually occur between the ages of five and thirteen. In each of the four cases to be described, the injury was caused by a fall on the outstretched hand. The force is transmitted along the radius and impacts the head against the capitellum. The head is held firmly by the annular ligament, and the proximal portion of the shaft is secured by the supinator and the biceps brachii muscles. The fracture occurs at the weak,

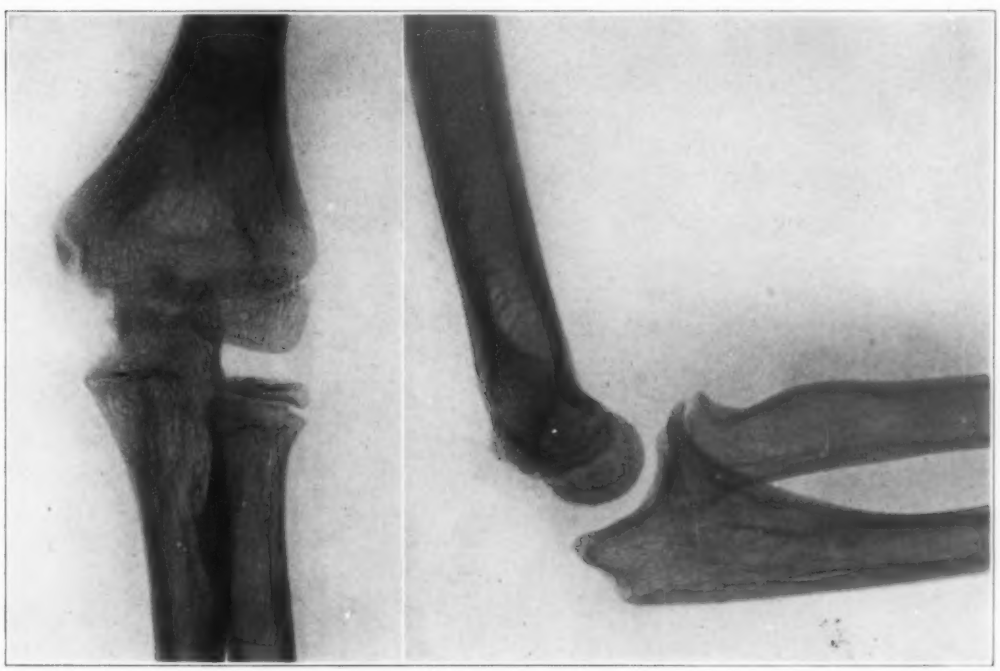

FIG. 1

Case 1. Fracture of the neck of the radius three and a half years after reduction.

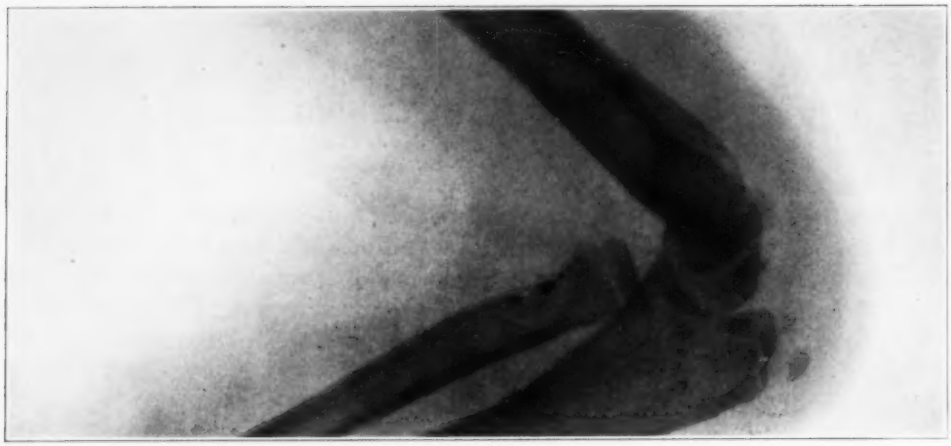

FIG. 2-B
Fracture of the neck of the radius after reduction.

FIG. 2-A
Case 2. Fracture of the neck of the radius before reduction.

FIG. 2-C
Fracture of the neck of the radius fourteen weeks after reduction.

unprotected neck of the radius. The proximal fragment is displaced outward and forward. Occasionally the fragment is displaced outward and backward.

The manipulation is performed under general anaesthesia and roentgenographic control. Immediately after reduction, roentgenograms are made. Reduction is complete when the articular surfaces of the radius and capitellum are parallel. (In the event that reduction has been incomplete, a second and even a third attempt should be made. In Case 2, three attempts were necessary before a satisfactory reduction was obtained.) The extremity is immobilized in plaster for three weeks, with the elbow held in 90 degrees of flexion and the forearm in complete supination.

CASE REPORTS

Case 1. S.M., aged eight, sustained a fracture of the neck of the right radius on April 30, 1941. Under general anaesthesia the fracture was reduced by the Patterson manipulation. The elbow was immobilized in plaster for three weeks in 90 degrees of flexion, with the forearm in complete supination. On July 17, 1941, eleven weeks after reduction, there was a complete and painless range of motion of the right elbow and forearm. Roentgenograms (Fig. 1) made on September 14, 1944, show no evidence of the fracture, except the subperiosteal ossification of the neck of the radius as seen on the lateral view.

Case 2. R.E.B., aged seven, sustained a fracture of the neck of the right radius on June 16, 1944. The patient was first seen on the following day. Under general anaesthesia the fracture was manipulated and reduced by the Patterson manoeuvre. Figures 2-A and 2-B show the position of the proximal fragment before reduction (outward and backward displacement), and the complete replacement of the fragment immediately after reduction. The articular surfaces of the radial head and the capitellum were parallel. The elbow was immobilized in plaster, as described in Case 1, and the plaster was worn for three weeks. The patient was last examined on September 21, 1944, fourteen weeks after manipulation. She presented a complete and painless range of motion of the elbow and forearm.

Case 3. J.M., aged six, sustained a fracture of the neck of the left radius on June 20, 1944. Treatment already described was employed, and Figures 3-A, 3-B, and 3-C show the fracture before and after reduction.

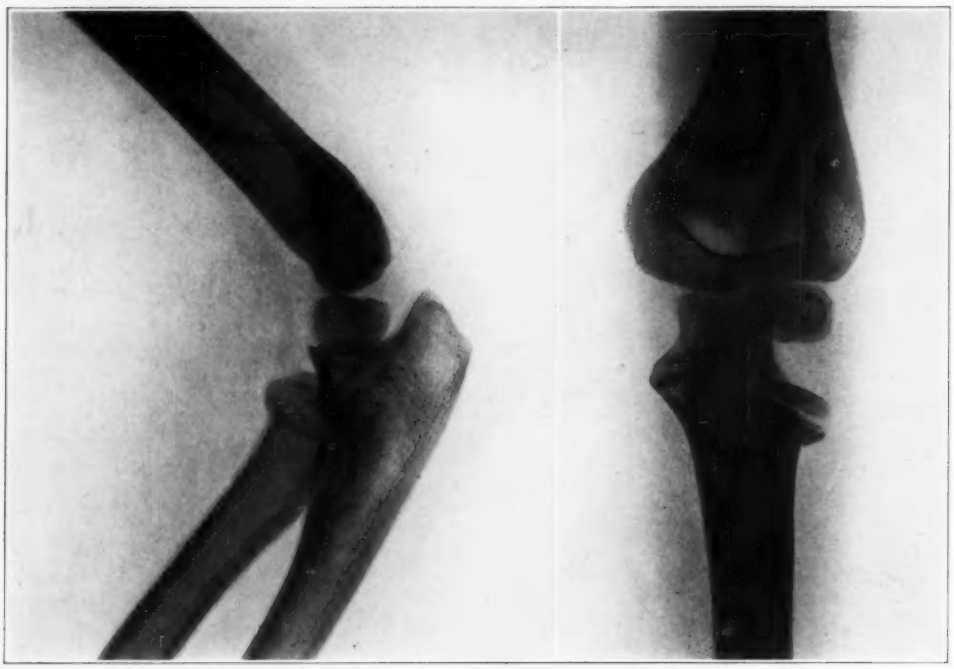

FIG. 3-A
Case 3. Fracture of the neck of the radius before reduction.

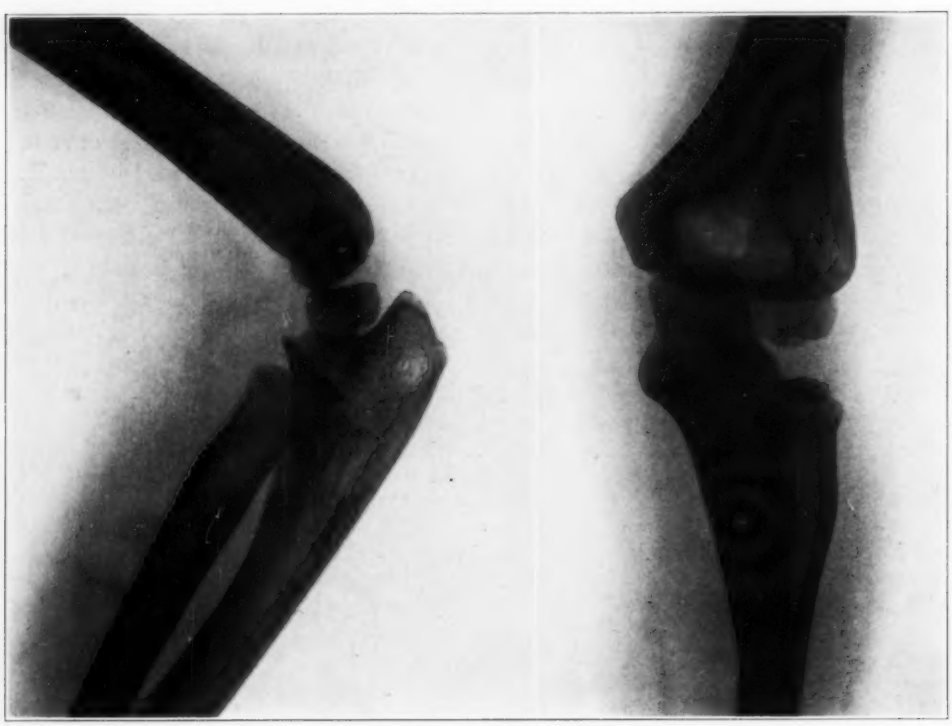

FIG. 3-B
Fracture of the neck of the radius after reduction.

FIG. 3-C
Fracture of the neck of the radius fifteen weeks after reduction.

The patient was last examined fifteen weeks after manipulation. He presented a complete and painless range of motion of the elbow and forearm.

Case 4. H.R., aged nine, sustained a fracture of the neck of the left radius on June 21, 1944 (Fig. 4-A). The fracture was reduced four hours later under general anaesthesia by the Patterson manipulation. Figure 4-B, made immediately after reduction, shows the improved position of the displaced proximal fragment, but complete reduction has not been obtained. The articular surfaces of the radius and the capitellum were not

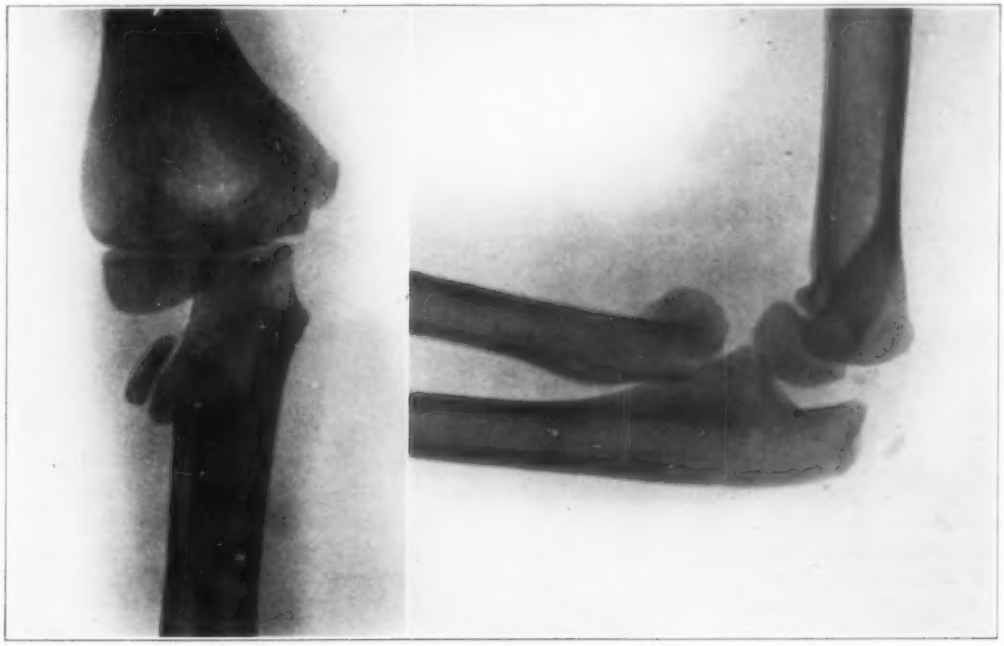

FIG. 4-A
Case 4. Fracture of the neck of the radius before reduction.

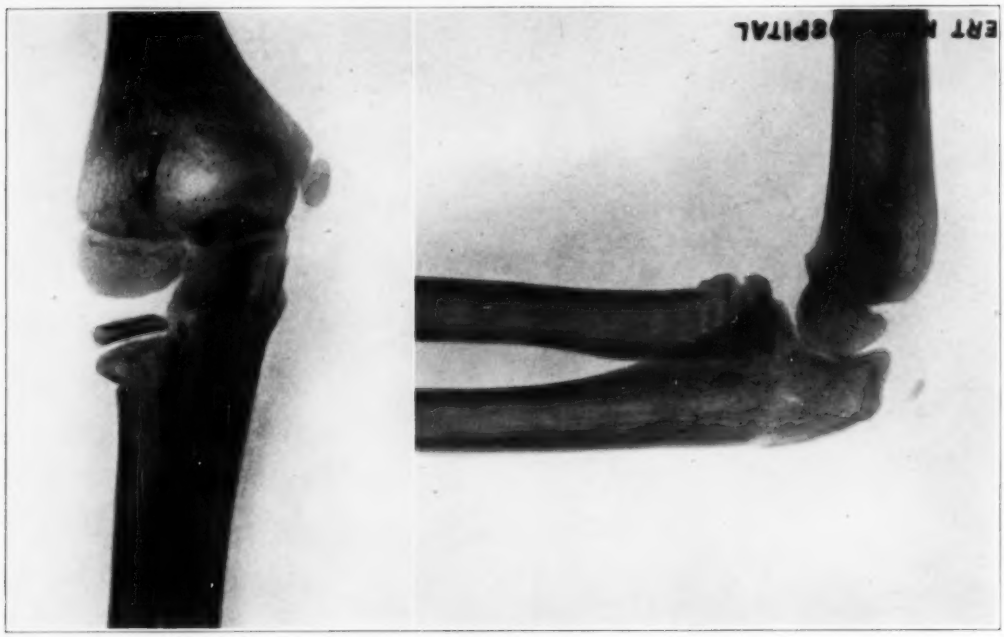

FIG. 4-B
Fracture of the neck of the radius after reduction.

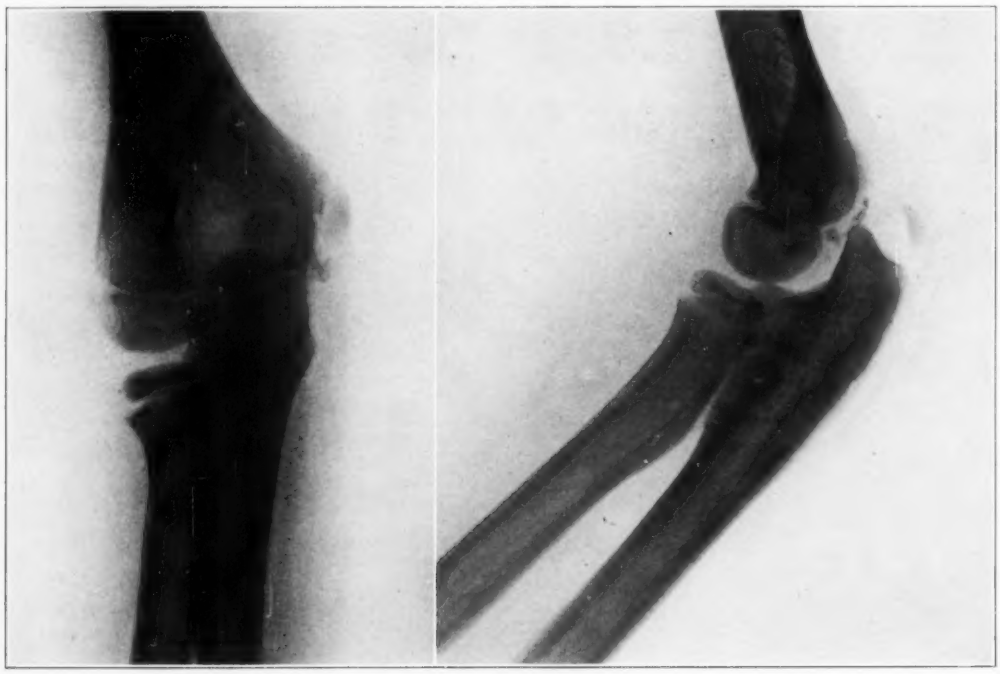

FIG. 4-C
Fracture of the neck of the radius fourteen weeks after reduction.

quite parallel. The elbow was immobilized in plaster for three weeks in 90 degrees of flexion with the forearm in complete supination. The patient was last examined on September 20, 1944. He did not complain of pain. Pronation and supination were complete, but there was 5 degrees of limitation of flexion and extension. Figure 4-C, made on September 29, 1944, shows that the improved position has been maintained fourteen weeks after manipulation. It is to be noted that the articular surfaces of the radius and the capitellum are not completely parallel.

SUMMARY

1. Four cases are reported of fracture of the neck of the radius in children with displacement of the proximal fragment in which satisfactory results were obtained by the Patterson manipulation.

2. It is recommended that this conservative treatment be tried in all similar cases before operative intervention is undertaken.

3. Every effort should be made to secure complete reduction. When the displaced fragment has been completely replaced, as evidenced by the parallel positions of the articular surfaces of the radius and the capitellum, complete motion is restored. When reduction has been incomplete, there is some residual limitation of motion, as in Case 4.

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WIRE FIXATION IN ACROMIOCLAVICULAR DISLOCATION

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Any inflexible immobilization used in the treatment of acromioclavicular dislocation should be of a temporary nature, since permanent rigid fixation of this joint, either by bony ankylosis or by the introduction of a foreign body into the tissues, is difficult to obtain and, when achieved, results in a disability as great as, or greater than, that which accompanies an unstable articulation.

Recent studies [1] on shoulder-joint function have clearly demonstrated the reason for the failure of operative procedures which attempt to make an unyielding union between the clavicle and the acromion. It has been shown that the clavicle, in addition to other motions usually attributed to it, rotates on its long axis up to 45 degrees when the arm is abducted to 180 degrees, and that restriction of the clavicular rotation may cause an inhibition of abduction at the shoulder joint even in the early phases of this motion.

In 1940, Murray reported a closed method of temporary wire fixation in acromioclavicular dislocations, and later Phemister modified the procedure by using threaded-wire fixation, combined with an open reduction. It is the purpose of the present paper to add to this method a simple means of maintaining reduction while the wires are being introduced, and to report on twenty patients treated in this way at the United States Naval Hospital in San Diego.

The degree of instability of the dislocations was varied, but in every instance there was definite disabling relaxation of the joint. In four patients, there was sufficient relaxation of the clavicle to determine that the coracoclavicular ligament had been com-

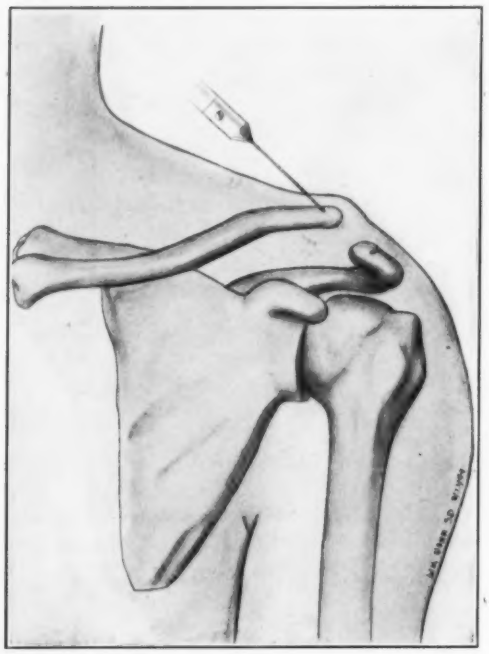

FIG. 1

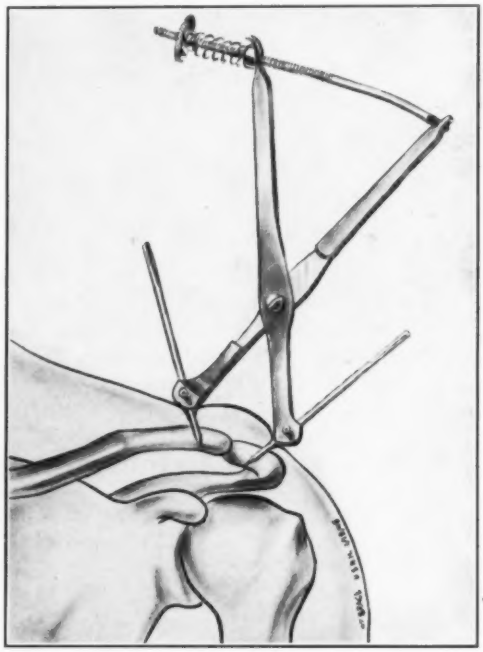

FIG. 2

Fig. 1: Placement of drill holes for towel clamp.
Fig. 2: A specially designed instrument replacing the towel clamp, maintaining reduction during the procedure. One-eighth inch Steinmann pins are used.

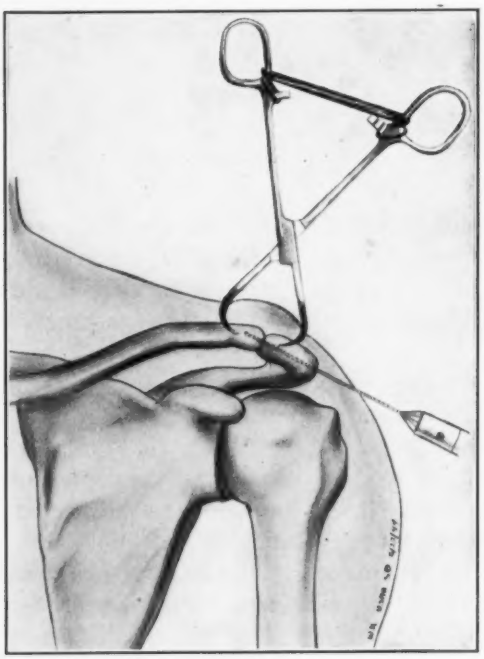

FIG. 3

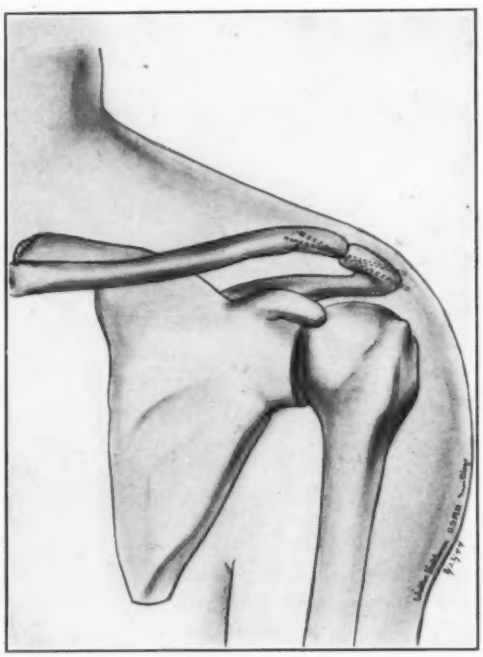

FIG. 4

Fig. 3: Anteroposterior check for position of first wire.
Fig. 4: Completed fixation with wires cut beneath the skin surface.

TABLE I

FIRST TWELVE CASES

Number	Name	Date of Injury	Days Between Injury and Fixation	Duration of Fixation (*Days*)	Interval Between Removal of Pins and Last Check-up (*Days*)
1	G.J.K.	Oct. 7, 1943	2	73	327
2	F.L.R.	Oct. 20, 1943	6	55	328
3	M.M.W.	Feb. 8, 1944	24	61	249
4	J.M.V.	Feb. 11, 1944	4	48	283
5	F.M.S.	Feb. 18, 1944	1	62	266
6	M.E.N.	Mar. 26, 1944	9	63	213
7	J.F.S.	Mar. 29, 1944	3	61	225
8	J.(n)T.	Apr. 5, 1944	20	66	105
9	M.M.B.	Apr. 25, 1944	4	66	285
10	D.R.B.	June 3, 1944	5	61	154
11	F.I.G.	June 22, 1944	2	58	152
12	H.J.D.	June 23, 1944	1	53	145
Average			7	61	228

pletely ruptured; while in one shoulder, the relaxation was so complete that it could be determined that all ligamentous and capsular structures on the distal third of the clavicle had been severed.

PROCEDURE

A general anaesthetic was used since it was thought that the injection of a local anaesthetic would distort the tissues and complicate the procedure.

The shoulder is prepared for the application of wires in the usual manner. A drill hole, 3/32 of an inch in diameter, is made through the superior cortex of the clavicle, one-half inch from the distal end. The hole is made at an angle of 45 degrees to the surface of the bone directed from the medial aspect laterally. A similar hole is drilled into the acromion opposite the joint, with the drill directed from the lateral aspect medially (Fig. 1).

The points of a towel clamp are inserted into the holes and held in position by a rubber band wound through the finger rings, with the loops hooked over the projecting snap lock. No attempt should be made to completely close the clamp. A more elaborate instrument was designed for this purpose (Fig. 2), and it has some advantages over the towel clamp and rubber band. By leverage on the clamp it is now an easy matter to place the clavicle and acromion in their normal relationship. While holding this position, a 3/32-inch pointed stainless-steel wire, nine inches long, is drilled from lateral to medial through the anterior portion of the acromion, across the joint space and down the medullary canal of the clavicle, for about one inch (Fig. 3). Roentgenograms in the anteroposterior and axillary projections are made at this time to check the accuracy of reduction and placement of the wire. (After experience with the procedure these control roentgenograms may be omitted. However, it is strongly urged that on the first few attempts, both views of the joint be taken.) A second wire is then inserted through the acromion, three-fourths of an inch posterior to the first. This wire is directed so that it also passes across the joint into the distal end of the clavicle. (At first some difficulty will be encountered when the wires are started into the flat, tapered, lateral edge of the acromion, but after a few trials this difficulty is overcome.) When the wires are in place, they are cut as short as possible by forcing the skin down with the blades of the cutter (Fig. 4). Two months later these wires are removed under a local anaesthetic through a small stab incision.

The men were advised not to use the shoulder in strenuous exercises, but no form of external immobilization was applied. It was known that several of the patients undertook rather severe types of physical exertion during the period of fixation, but few ill effects were noted.

RESULTS

In Case 15 the wires broke at the end of fifty-two days, and it was necessary to remove the proximal portion of the wires through an incision over the outer end of the clavicle; however, when the patient returned to full duty two months later, the joint was stable and painless. In approximately 25 per cent. of the cases, the wires loosened before the two-month period had elapsed and migrated toward the skin. In these cases the wires were simply pushed back, and the man was instructed to restrict the use of his arm until time for removal of the fixation.

Because of the nature of the Service, it is impossible to communicate with many of these men after they return to duty. However, the interval given in the last column in Table I was determined by the fact that those who had returned to duty were still in that status. It can be reasonably assumed that if the shoulders had been causing any appreciable discomfort, these men would not be carrying out the strenuous and exacting duties of their ratings.

Twelve of the men have been returned to full duty. At the time of their discharge from the hospital, all had complete range of motion in the shoulder joint. Four complained of some discomfort in the extremes of abduction, but the pain was not severe enough to constitute a disability. Five additional cases are ready for full duty as far as the acromioclavicular joint disability is concerned, but they are prevented from returning by complicating factors. M. M. W. (Case 3) was assigned to limited duty, because of a disability resulting from a fractured tibia. In Case 11, an acute febrile disease developed, from which the patient is now convalescing. Of the more recent cases (not included in Table I), one patient has not returned to duty because of conditions other than medical; another patient has a complicating vertebral compression fracture; and a third patient had a stable joint with a full range of shoulder motion when last seen, but was transferred to another duty and follow-up observations cannot be made.

J. T. (Case 8) remained on duty for three months following his discharge from the hospital. He then fell down stairs and re-dislocated the same acromioclavicular joint. He was not seen for treatment until eight weeks following this second injury. In the patient's estimation, the second injury was more severe than the injury causing the original dislocation. The pins were replaced, but the elapsed time was considered too great for simple healing, and an operative repair of the coracoclavicular ligament was done at the same time. The end result of the second injury has not been determined.

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SURGICAL APPROACHES TO THE KNEE JOINT*†

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In the development of surgical approaches, one of two methods is usually employed. The first method might be termed the approach which is planned to avoid the exposure of vital structures; and the second, the approach which is designed to expose them. In the first case, the incision is placed at sufficient distance from vital structures to obviate the necessity of their exposure. This method is to be recommended if adequate exposure of the lesion or lesions can be secured, and if there is only a remote possibility of injury to vital structures. The writers, however, stress the importance of the use of the second method in all instances where the incision is planned to give the most direct access to the site of the pathological changes, regardless of the proximity of vital structures. In such cases, the exposure of those structures in the path of the dissection, or in the immediate vicinity, is the paramount issue. Failure to observe this fundamental principle, the necessity for exposure, may result either in a permanent loss of function or in a surgical disaster. The operating surgeon should be so familiar with the anatomy that he can plan his own approach, basing it upon the anatomical accessibility of the lesion. This fundamental knowledge of anatomy is most important in the surgery of bones and joints. Before proceeding with a description of the surgical approaches to the knee joint, therefore, some pertinent, general anatomical considerations are essential.

GENERAL ANATOMICAL CONSIDERATIONS

The knee joint, the largest articulation in the human body, is formed by the condyles of the femur, the tuberosities of the tibia, and the patella. From the standpoint of its bony architecture, it is a weak joint. For strength and stability it is dependent upon its supporting structure,—the fibrous capsule, reinforced by ligaments and muscles.

Capsule

It is difficult to find a satisfactory description of the capsule of the knee in textbooks of anatomy and surgery. It is often described as a continuous structure of fibers, completely investing the joint; whereas the true fibrous portion of the capsule exists only on its posterior aspect, where it extends from the proximal margin of the articular surface of the femur and intercondylar line to the posterior border of the head of the tibia. Added strength is given to this part of the capsule by the oblique popliteal ligament, which extends upward and outward across the posterior part of the joint to the medial border of the lateral condyle of the femur. Further reinforcement is obtained laterally by a thickened portion of the capsule, which bridges the penetrating tendon of the popliteus muscle, attaching itself above to the posterior aspect of the femoral epicondyle and below by two slips,—one to the head of the fibula, and another to the margin of the tibial condyle. Additional support is provided to the fibrous capsule by the collateral and the cruciate ligaments.

In contradistinction to the posterior part of the capsule, the anterior portion is ill-defined. It is composed of the quadriceps tendon, the patella, the infrapatellar tendon, and the blending of the fascia lata with the fibrous aponeuroses of the vasti muscles. A detailed description of these structures will be given under the section on approaches to

* Read at the Annual Meeting of The American Orthopaedic Association at Hot Springs, Virginia, June 1, 1944.

† This work was supported by the Florence Hellman Ehrman Donation for Crippled Children.

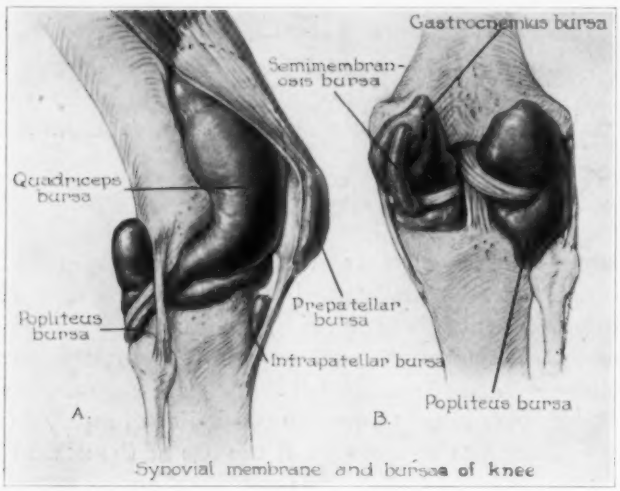

FIG. 1

A: Anterolateral aspects of the knee joint (Redrawn from Spalteholz).
B: Posterior aspect of the knee joint (Sweet).

the anterior aspect of the knee joint.

Synovia and Bursae

The synovial membrane lines the aponeurotic and the fibrous portions of the capsule. It extends upward beyond the articular surface of the distal end of the femur, on the anterior aspect of the joint, in the form of a cul-de-sac which lies under cover of the tendon of the quadriceps muscle. The upper part of this cul-de-sac usually communicates with the suprapatellar bursa. A pouchlike extension or diverticulum is prolonged posteriorly and distally on the tendon of the popliteus muscle. This diverticulum sometimes communicates with the capsule of the upper tibiofibular joint. A second pouch of synovial membrane often connects with a bursa which lies between the tendon of the semimembranosus and the tendon of origin of the inner head of the gastrocnemius (Fig. 1).

In the posterior part of the joint, the cruciate ligaments are enveloped in a duplication of the synovial membrane which renders them extrasynovial. The infrapatellar fat pad, triangular in shape, lies between the distal part of the patella and the upper, anterior margin of the tibia. It is rendered extrasynovial by a fold of synovial membrane, the lateral free margins of which extend to the intercondylar notch and are known as the ligamenta alaria. The central portion of this ligamentous fold is known as the ligamentum mucosum.

The semilunar cartilages (menisci) lie between the outermost portions of the articulating surfaces of the femur and the upper end of the tibia. They are wedge-shaped structures, free at their inner margins, but attached to the tibia at their outer surfaces by the coronary ligaments. Each cartilage presents two extremities or horns, which are fixed by fibrous attachments to the intercondylar eminence on the upper surface of the tibia (Fig. 2).

The numerous bursae about the knee joint are described in detail in various textbooks of anatomy. In this paper, the writers will deal briefly with those of constant occurrence and of surgical importance. On the anterior aspect of the knee, there are the so-called prepatellar bursae, which lie between the skin and the anterior surface of the patella and the patellar ligament. There are two others, termed the superficial and deep infrapatellar bursae; the former lies between the skin and infrapatellar tendon, while the latter lies between the tendon and the anterior surface of the upper end of the tibia. On the lateral side of the joint, there are usually four bursae,—one between the lateral head of the gastrocnemius and the capsule, another between the fibular collateral ligament and the tendon of the biceps, a third between the fibular collateral ligament and the tendon of the popliteus, and a fourth between the tendon of the popliteus and the lateral condyle of the femur; the fourth bursa is usually a direct extension of the synovial membrane of the joint. On the medial side of the joint, a bursa lies between the medial head of the gastrocnemius and the tendon of the semimembranosus, and often communicates with the knee joint; a second bursa lies superficially between the tibial collateral ligament and the tendons of the sartorius, gracilis, and semitendinosus; while a third is placed beneath the tendon of the semimembranosus at its attachment to the head of the tibia.

In addition, Brantigan and Voshell describe bursae which lie in relation to the tibial collateral ligament; as many as three of these bursae have been found in a single joint. The principal locations of these bursae are: (a) between the tibial collateral ligament and the capsule of the joint, (b) between the tibial collateral ligament and the medial meniscus, (c) directly over the meniscus, (d) inferior to the meniscus, and (e) between the tibial collateral ligament and the tibia, but not related to the meniscus.

Blood Supply

The blood supply to the knee joint and its surrounding structures is furnished by the genicular branches of the popliteal artery, the arteria genus suprema, a branch of the femoral artery, the descending branch of the lateral circumflex artery, and the recurrent branch of the anterior tibial artery. The terminals of these vessels form a rich network over the bones, ligaments, and tendons, and are arranged in three arterial arches on the anterior aspect of the joint. The uppermost of these arches lies in the midst of the superficial fibers of the quadriceps muscle, near the upper border of the patella. The two lower arches are directed transversely through the fatty tissues behind the patellar ligament. The superomedial and superolateral genicular arteries are given off by the popliteal artery proximal to the intercondylar notch. They pass inward and outward beneath the hamstring tendons directly upon the femur, pierce the inner and outer intermuscular septa, and anastomose in the vastus medialis and vastus lateralis, respectively, with the arteria genus suprema and the descending branch of the lateral circumflex artery. The inferomedial and inferolateral genicular arteries are given off from the popliteal artery at the level of the lower border of the oblique popliteal ligament. They pass inward and outward close to the bone, with the inferomedial passing along the upper border of the popliteal muscle and beneath the tibial collateral ligament. The inferolateral genicular artery passes along the upper border of the fibular head of origin of the soleus, around the neck of the fibula, and then beneath the fibular collateral ligament. The recurrent branch of the anterior tibial artery is given off after this main vessel has passed through the interosseous membrane. It proceeds upward to join in the anastomosis on the anterior aspect of the joint (Fig. 3).

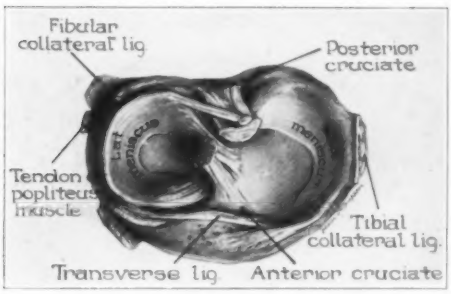

FIG. 2

The upper surface of the tibia, showing the relationship of the semilunar cartilages and the cruciate ligaments (Redrawn from Grant's Atlas of Anatomy).

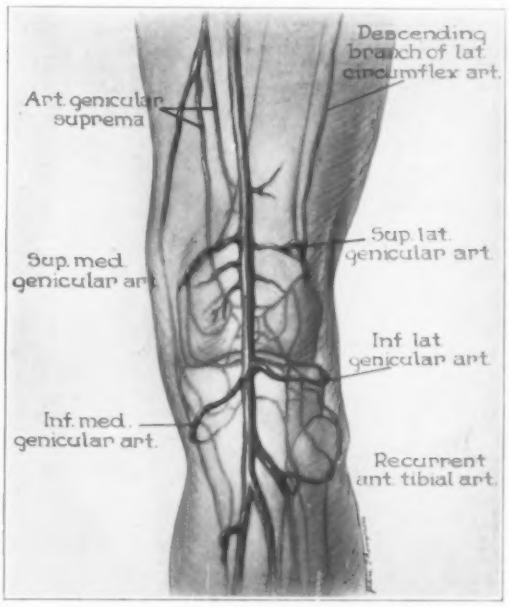
Descending branch of lat. circumflex art.
Art. genicular suprema
Sup. lat. genicular art.
Sup. med. genicular art.
Inf. lat. genicular art.
Inf. med. genicular art.
Recurrent ant. tibial art.

FIG. 3

An anatomical sketch, showing the collateral circulation about the knee.

Cutaneous Nerves

The nerves which supply the skin over the various aspects of the knee are:

1. Anterior division of the lateral cutaneous nerve of the thigh.
2. Intermediate cutaneous nerve of the thigh.
3. Anterior and posterior divisions of the medial cutaneous nerve of the thigh.
4. Saphenous nerve.
5. Posterior cutaneous nerve of the thigh.
6. Posterior cutaneous nerve of the leg.
7. Lateral cutaneous nerve of the leg.
8. Anastomotic peroneal nerve of the leg (Fig. 4).

An accurate anatomical knowledge of the cutaneous nerves is of importance to the surgeon, because their severance may cause temporary or permanent disturbance of sensation, or may lead to the formation of painful neuromata. Division of the infrapatellar branch of the saphenous nerve at the time of an operation for removal of the internal semilunar cartilage (medial meniscus) may cause a painful neuroma with symptoms which are similar to those for which the cartilage was removed. The writers have seen several such cases, in which removal of the neuromata gave complete relief of symptoms. These cutaneous nerves are of further significance, because the operating surgeon can use them as anatomical landmarks and guides to deeper structures. For example, the posterior cutaneous nerve of the calf can be traced to its origin from the posterior tibial nerve. A needless and often prolonged search in the popliteal fat for the sciatic nerve and its divisions and the popliteal vessels is thus avoided. A further description of the various cutaneous nerves about the knee will be given in the appropriate sections.

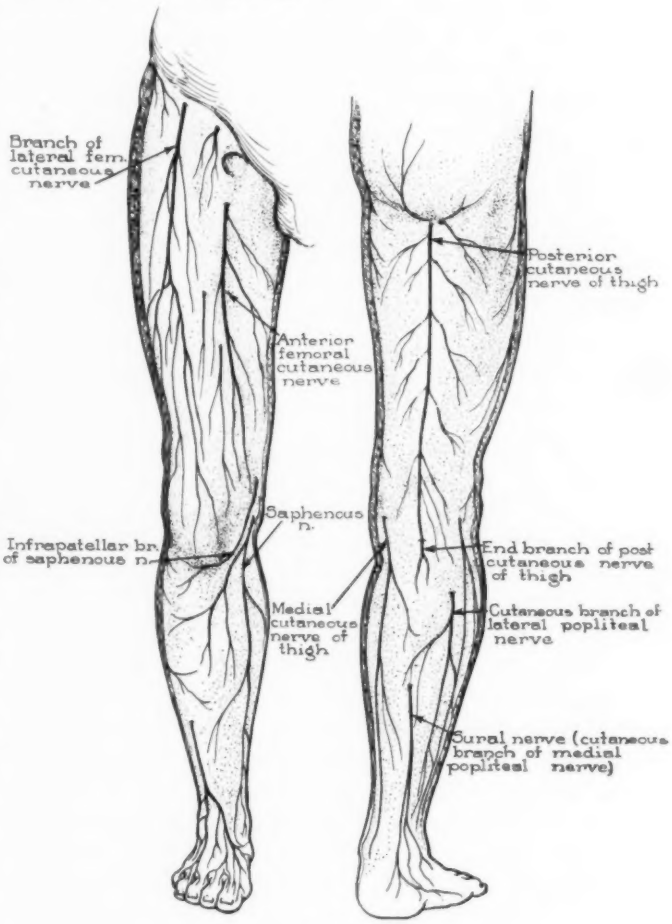
Branch of lateral fem. cutaneous nerve
Anterior femoral cutaneous nerve
Saphenous n.
Infrapatellar br. of saphenous n.
Medial cutaneous nerve of thigh
Posterior cutaneous nerve of thigh
End branch of post. cutaneous nerve of thigh
Cutaneous branch of lateral popliteal nerve
Sural nerve (cutaneous branch of medial popliteal nerve)

FIG. 4
The cutaneous nerves of the lower extremity.

SURGICAL APPROACHES

The surgical approaches to the knee joint will be described according to the following outline:

I. Approaches to the Anterior Aspect of the Knee Joint (Fig. 6).
   A. The parapatellar incisions.
      1. The median parapatellar incision (von Langenbeck).
      2. The S-shaped parapatellar incision (Payr).
      3. The oblique parapatellar incision (Erkes).
      4. The lateral parapatellar incision (Kocher).

B. Incisions which divide the patella.
   1. Vertical division of the patella (Brackett and Hall, Jones).
   2. Transverse division of the patella (von Volkmann).
   3. Sagittal division of the patella (Devine).
   4. Oblique division of the patella (Bougot and De La Rue).

C. Incisions which divide the tendon of the quadriceps muscle.
   1. Plastic division of the quadriceps tendon (Putti, Campbell).
   2. Plastic division of the quadriceps tendon (Coonse and Adams).

D. Incisions which divide the tendon of the patella transversely.
   1. The U-shaped incision (Textor).
   2. The H-shaped incision (Ollier).

II. Approaches to the Medial Aspect of the Knee Joint.
   A. The S-shaped incision.
   B. The straight or curved incision.

III. Approaches to the Lateral Aspect of the Knee Joint.
   A. The S-shaped incision.
   B. The straight or curved incision.

IV. The Approach for the Removal of the Semilunar Cartilages (the Menisci).
   A. Partial removal of the internal semilunar cartilage.
   B. Complete removal of the internal semilunar cartilage.
   C. Partial removal of the external semilunar cartilage.
   D. Complete removal of the external semilunar cartilage.

V. Bilateral Incisions.
   A. Exposure of the popliteal face of the femur (Henry).
   B. Approach for epiphyseodesis (Abbott and Gill).
   C. Removal of loose bodies from the posterior compartment of the knee (Henderson).
   D. Posterior capsulotomy in flexion contractures of the knee (Wilson).

VI. Approaches to the Posterior Aspect of the Knee Joint.
   A. The mid-line approach through the popliteal space.

VII. Approaches for Drainage of Sepsis of the Knee Joint.
   A. Parapatellar approaches.
      1. Vertical (single, multiple, bilateral).
      2. Horizontal (bilateral).
   B. U-shaped incision.
   C. Posteromedial, tibial incision.
   D. Posteromedial, femoral incision (Klein).
   E. Incisions for counter-drainage on the posterolateral aspect of the knee.

I. *Approaches to the Anterior Aspect of the Knee Joint*

Surgical Anatomy: The quadriceps tendon is subdivided into three parts, readily discernible in a sagittal section through the middle of the patella (Fig. 5). The anterior subdivision is the tendon of insertion of the rectus femoris, while the intermediate subdivision is the common tendon of the vastus medialis and the vastus lateralis, and the posterior subdivision is the tendon of the vastus intermedius. The genu articularis muscle joins the tendon of the vastus intermedius, and also provides a slip which inserts into the apex of the suprapatellar synovial pouch. Between the adjacent margins of the vasti, a fascial sling is formed, which acts as a hammock or cradle for the tendon of the rectus femoris. This sling, traced laterally, blends with the aponeuroses of the vasti muscles. The aponeurosis at the lower margin of the vastus medialis divides into two distinct layers over the anteromedial aspect of the knee. The anterior layer passes across the patella in the form of a continuous sheet which blends with the aponeurosis of the vastus lateralis. Below the

level of the tibial tubercle it becomes continuous with the deep fascia of the leg. The posterior or deep layer of the aponeurosis of the vastus medialis is inserted into the medial border of the patella and the upper margin of the tibia. The synovial membrane lies behind this layer. On the outer aspect of the knee, the deep fascia and aponeurosis blend to form a single layer which is inserted into the lateral margin of the patella and the upper border of the tibia. This layer fuses with the iliotibial band and the fascia enclosing the biceps muscle. The operating surgeon should note the various fascial layers which facilitate exposure of the joint and closure of the wound. On the anteromedial surface, four layers of fascia are found,—namely, the superficial fascia, often indistinct and of little importance, the fascia lata, sometimes blended with the anterior layer of the aponeurosis of the vastus medialis, and the deep layer of the aponeurosis of the vastus medialis. On the anterolateral aspect of the knee, the blending of the fibrous aponeurosis with the iliotibial tract is so intimate that only two layers are distinguishable, the superficial fascia and a layer of deep fascia and fibrous aponeurosis (Saunders).

The important landmarks are the quadriceps tendon, the patella, the patellar tendon, the condyles of the femur, and the tuberosities of the tibia. With the knee in extension, the quadriceps tendon forms an obtuse angle with the patella and the patellar tendon of approximately 170 degrees (Callander). Curvilinear incisions are, therefore, preferable for those approaches in which either the patella or the aponeurotic expansions of the vasti are divided to enter the joint. With the knee in flexion, the iliotibial tract and the biceps tendon stand out prominently as they pass to their respective insertions into the lateral margin of the tibia and the head of the fibula. On the posteromedial surface of the joint the tendons of the sartorius, gracilis, and semitendinosus are seen where they insert into the medial aspect of the upper end of the tibia.

A. *The Parapatellar Incisions*

1. The median parapatellar incision (von Langenbeck).

a. *Indications:*

(1) Exploration of the joint;
(2) Synovectomy;
(3) Osteochondritis dissecans;
(4) Removal of loose bodies (joint mice);
(5) Repair of the cruciate ligaments;
(6) Removal of the infrapatellar fat pad.

b. *Position of the patient:* The patient is supine with the knee on a sandbag and flexed from 20 to 30 degrees.

(NOTE: The position of the patient and the same anatomical landmarks are used in all median parapatellar incisions.)

c. *Landmarks:*

(1) Tibial tubercle;
(2) Patellar tendon;
(3) Patella;
(4) Quadriceps tendon;
(5) Vastus medialis;
(6) Adductor tubercle.

d. *Incision:* The incision of the skin is begun over the medial portion of the quadriceps tendon, four inches above the upper border of the patella (Fig. 6, *C*). It is continued downward in a gentle curve following the medial margin of the quadriceps tendon, the medial border of the patella, and the patellar tendon. It next crosses the upper end of the tibia, and ends inferior to the tubercle of the tibia. One of two methods of exposure of the joint may be followed. In the first method, the deep fascia is incised and the quadriceps tendon is defined. This tendon is split in a vertical direction one-third of an inch lateral to its medial border. The incision is continued downward with division of the

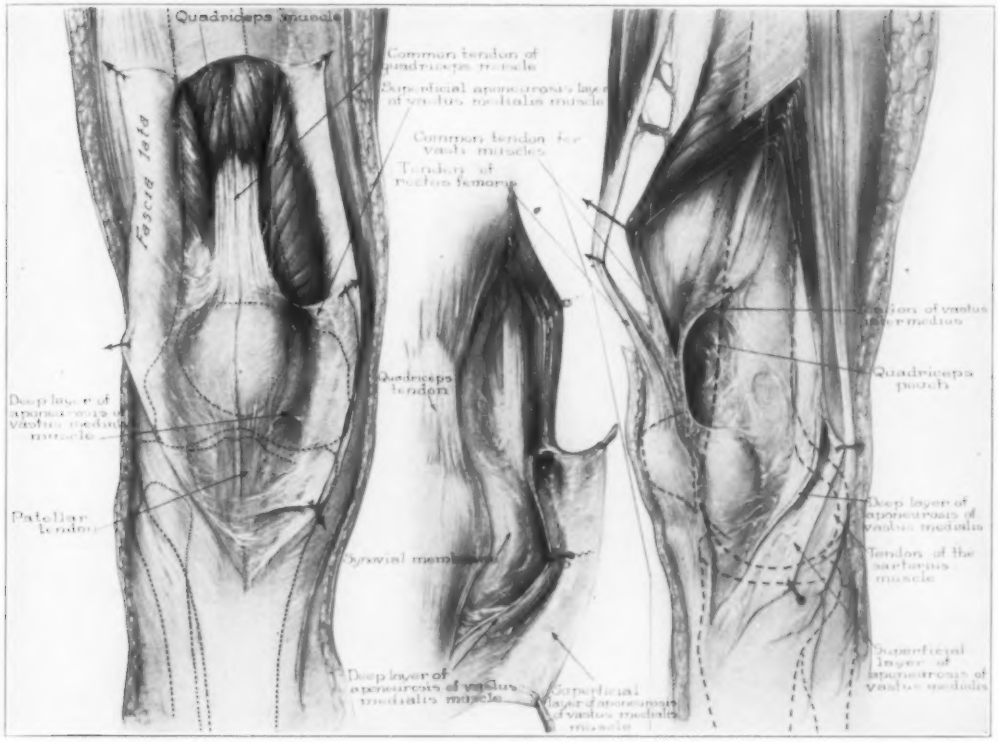
Quadriceps muscle
Common tendon of quadriceps muscle
Superficial aponeurosis layer of vastus medialis muscle
Common tendon for vasti muscles
Tendon of rectus femoris
Fascia lata
Quadriceps tendon
Deep layer of aponeurosis of vastus medialis muscle
Patellar tendon
Synovial membrane
Deep layer of aponeurosis of vastus medialis muscle
Superficial layer of aponeurosis of vastus medialis muscle
Quadriceps pouch
Deep layer of aponeurosis of vastus medialis
Tendon of the sartorius muscle
Superficial layer of aponeurosis of vastus medialis

FIG. 5

Anatomical dissections, showing the three divisions of the quadriceps tendon, the synovial membrane, the quadriceps pouch, and the aponeurotic insertions of the vasti muscles into the patella and tibia.

aponeurosis of the vastus medialis following the medial border of the patella and the patellar tendon. Just below the tubercle of the tibia, the periosteum is divided obliquely and reflected laterally for a short distance to free only the medial portion of the insertion of the patellar tendon. This procedure facilitates displacement of the patella.

An alternate method is described by Fisher, in which the skin is reflected laterally until the lateral margin of the patella is reached. A straight incision is then made through three layers of fascia over the quadriceps tendon, the patella, and the patellar tendon (Fig. 7). These three layers are the superficial fascia, the fascia lata, and the superficial layer of the aponeurosis of the vastus medialis. Medial to the patella the deep fascia and superficial layer of the aponeurosis blend and are generally reflected as one layer. The deep layer of the fibrous aponeurosis is now seen as a solid sheet, though infrequently it is in the form of cords or retinacula. The synovia and deep apondurosis are divided medial to the patella, and the quadriceps tendon is separated in the line of its fibers just lateral to the insertion of the vastus medialis (Fig. 8). The patellar tendon is freed along its medial border to the level of the tibial tubercle, exposing the infrapatellar bursa. The patella is dislocated laterally to expose the interior of the joint. Greater access to the joint may be secured in four ways: (1) by division of the quadriceps tendon to a higher level, (2) by turning the upper end of the incision obliquely inward and separating the fibers of the vastus medialis, (3) by vertical section of the medial border of the alar ligament and adjacent fat pad, and (4) by freeing the patellar tendon subperiosteally on its medial aspect.

The structures which are exposed are:

(1) Quadriceps pouch;
(2) Condyles of the femur;
(3) Posterior surface of the quadriceps tendon, and the posterior surfaces of the patella and the patellar tendon;

(4) Infrapatellar fat pad;
(5) Ligamentum mucosum;
(6) Origin of the anterior cruciate ligament and the insertion of the posterior cruciate ligament (Fig. 9);
(7) Anterior margins of the upper end of the tibia and the semilunar cartilages.

The wound is closed with interrupted sutures to the deep layers of the fibrous aponeurosis and synovial membrane, to the fascia lata and the superficial layer of the fibrous aponeurosis directly over the center of the patella, and to the skin.

2. An S-shaped parapatellar incision has been described by Payr. The incision of the skin is begun four inches above the upper border of the patella, and is then curved

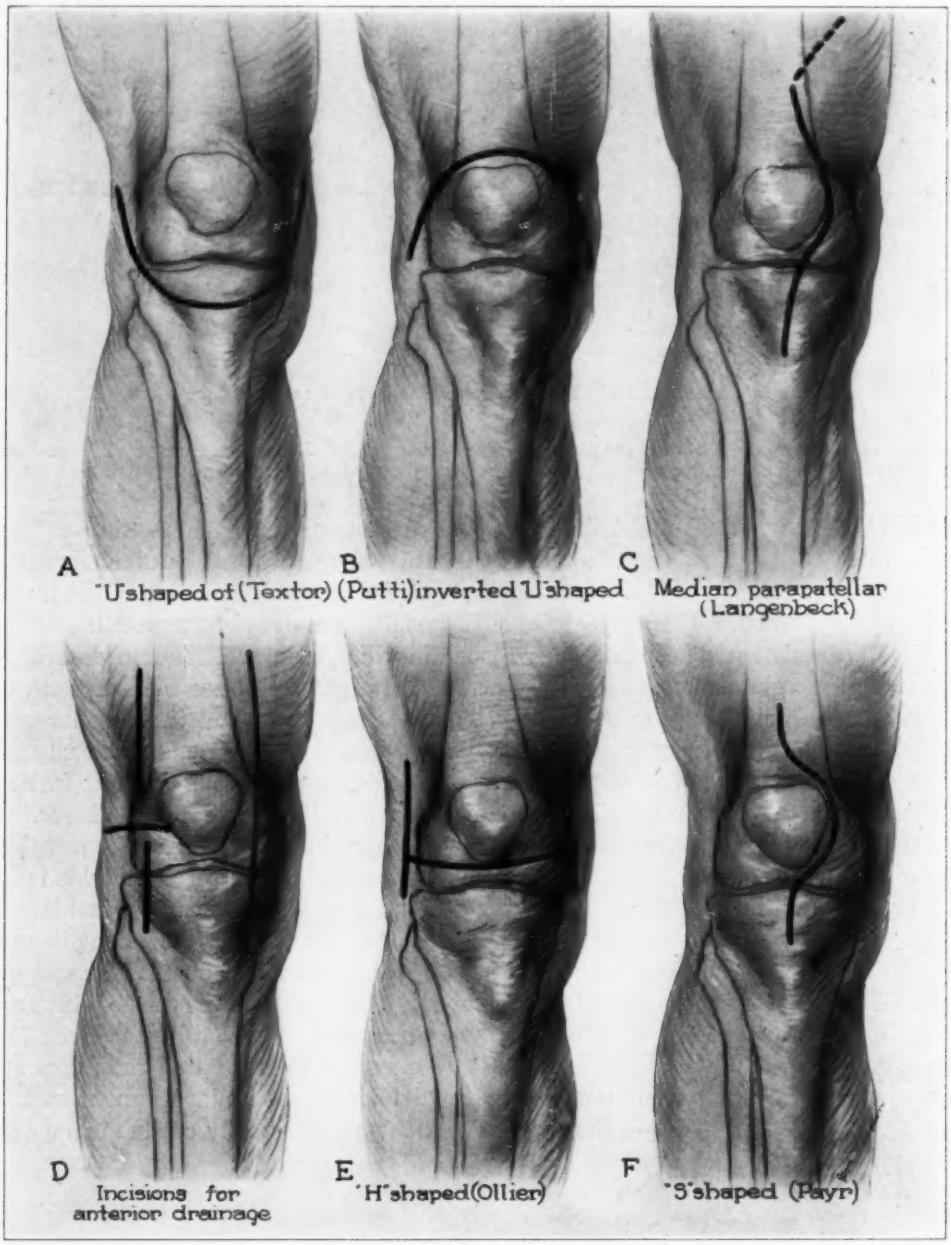

FIG. 6
The incisions on the anterior aspect of the knee.

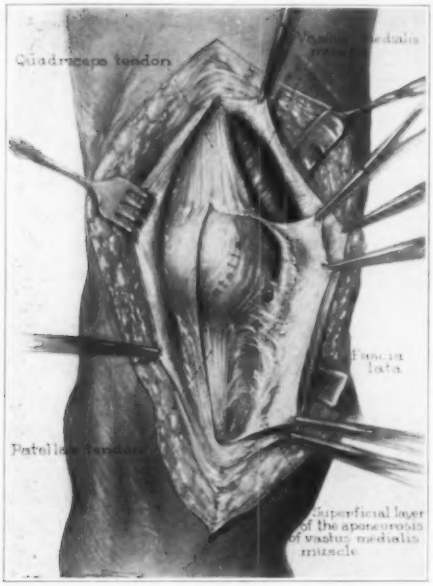

FIG. 7

FIG. 8

Fig. 7: The medial parapatellar incision, showing fascia lata and the superficial layer of the aponeurosis of the vastus medialis muscle, reflected from the anterior surface of the patella.

Fig. 8: The medial parapatellar incision, showing the fascia lata and the aponeurotic layers.

around its medial border to follow the medial margin of the patellar tendon to the tibial tubercle. The fibrous insertions of the vastus medialis into the quadriceps tendon are divided, and the fibrous aponeurosis of the vastus medialis is divided down to the level of the insertion of the patellar ligament into the tibial tubercle. The synovial membrane is then incised, and the patella is displaced to gain access to the joint.

3. The Erkes incision follows the grain of the skin (Fig. 10, *A*). It is begun on the medial surface of the medial epicondyle of the femur, and is continued downward across the anteromedial aspect of the joint to reach the insertion of the patellar tendon into the tibial tubercle. The fibers of origin of the vastus medialis are freed from the internal intermuscular septum to permit displacement of the patella, and thus obtain access to the joint. Erkes contends that by this method, together with stretching of the vastus medialis, he avoids division of the aponeurotic insertion of this muscle.

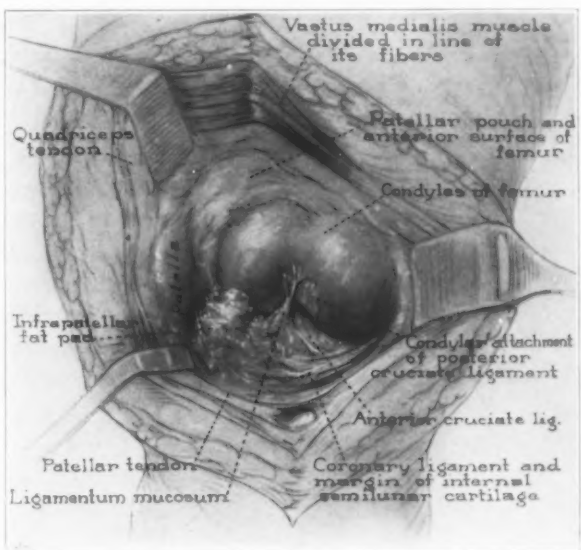
Vastus medialis muscle divided in line of its fibers
Quadriceps tendon
Patellar pouch and anterior surface of femur
Condyles of femur
Infrapatellar fat pad
Condylar attachment of posterior cruciate ligament
Anterior cruciate lig.
Patellar tendon
Ligamentum mucosum
Coronary ligament and margin of internal semilunar cartilage

FIG. 9

The structures which are exposed by the median parapatellar incision after the displacement of the patella.

4. Lateral parapatellar incision of Kocher (Fig. 10, *B*).

a. *Indications:*

(1) Exploration of the anterolateral aspect of the joint;

(2) Removal of loose bodies;

(3) Treatment of certain fractures in the lower end of the femur.

FIG. 10
A: The oblique parapatellar incision of Erkes.
B: The lateral incision of Kocher.

b. *Landmarks:*
(1) Tibial tubercle;
(2) Patellar tendon;
(3) Patella;
(4) Quadriceps tendon;
(5) Vastus lateralis;
(6) External condyle of the femur.

c. *Incision:* The incision is begun over the vastus lateralis on the lateral aspect of the joint. It is continued downward over the parapatellar region, and then curved forward over the tibial tubercle. The fibrous aponeurosis of the vastus lateralis and the synovial membrane are divided in much the same manner as in the medial parapatellar incision. In order to facilitate a medial displacement of the patella, the patellar tendon is freed subperiosteally or subcortically from the tibial tubercle.

The criticism of this method, made by Putti, is that sectioning of the bone to free the insertion of the patellar tendon into the tibial tubercle may be followed by non-union. Albee modified the Kocher approach by dovetailing the bone at the site of the insertion of the patellar tendon into the tibial tubercle.

B. *Incisions Which Divide the Patella* (These incisions have been largely discarded in favor of parapatellar incisions.)

1. Vertical division of the patella (Brackett and Hall, Jones).

a. *Indications:*
(1) Exploration of the anterior portion of the joint;
(2) Osteochondritis dissecans;
(3) Removal of joint mice.

b. *Position of the patient:* The patient is supine with the knee supported in about 60 degrees of flexion.

c. *Landmarks:* (The same landmarks are used in all methods of dividing the patella.)
(1) Quadriceps tendon;
(2) Patella;
(3) Patellar tendon;
(4) Tibial tubercle.

d. *Incision:* A curvilinear incision is made, following the obtuse angle formed by the quadriceps, the patella, and the patellar tendon. It is begun about three inches above the upper border of the patella. The quadriceps tendon, the patella, and the patellar tendon are divided longitudinally at the junction of their inner and middle thirds, the latter structure being sectioned to the level of its insertion into the tibial tubercle. This method allows displacement of the inner third of the bone to the inner side of the joint, and thereby gives wider exposure of the medial condyle of the femur. The patella is either split with an osteotome or sectioned with a saw. The parts exposed are the quadriceps pouch, the anterior part of the condyles of the femur, the anterior margins of

the semilunar cartilages, the anterior cruciate ligament, the insertion of the posterior cruciate, the infrapatellar fat pad, and the ligamentum mucosum.

2. Transverse sectioning of the patella, as advocated by von Volkmann, should be mentioned only to be condemned. The results following this procedure have been unsatisfactory, with permanent limitation of flexion of the knee.

3. Sagittal division of the patella is described by Devine in a well-illustrated article. He describes his operation in the following manner:

a. A curved incision is made, the middle of which is about one-half an inch below the lower margin of the patella. The flap of skin and fat is dissected upward and laterally until the quadriceps tendon, the anterior surface of the patella, and the patellar tendon are exposed.

b. With a butcher's saw, a cut is made, starting in the quadriceps tendon about one-half an inch above the upper margin of the patella, in a direction sloping backward through the tendon of the quadriceps, the patella, and the patellar tendon, and coming out of the latter on the posterior surface, one-half inch below the lower margin of the patella. This divides the patella into the anterior and posterior halves without disturbing its cartilaginous surfaces.

c. The assistant bends the knee; the patellar fragments are separated; and the lateral expansion of the joint is stretched tightly. The surgeon places a small hook under the lower margin of the upper fragment, turns its cartilaginous surface over; and, as the knee bends, he divides the fibers of the lateral expansions of the vasti muscles.

d. When the joint is closed, the fragments of the patella fall nicely into position and are sutured together with the quadriceps tendon. The synovial membrane and the quadriceps expansions are closed separately. The writers have not used this method.

4. Bougot and De La Rue describe two methods of approach by division of the patella; one is a vertical incision for lesions of the femur, which is similar to the ordinary split-patella incision, and the other is an oblique incision where the patella is divided obliquely from front to back for lesions involving the tibia. This oblique division of the patella, used in place of the vertical division, gives a good exposure of the articular cartilages, the ligaments, and the upper end of the tibia.

C. *Incisions Which Divide the Tendon of the Quadriceps Muscle*

1. Plastic division of the tendon of the quadriceps (Putti, Campbell).

a. *Indications:*

(1) Arthroplasty of the knee.

b. *Position of the patient:* The patient is supine with the knee flexed to from 25 to 30 degrees.

c. *Landmarks:*

(1) Condyles of the femur;
(2) Condyles of the tibia;
(3) Quadriceps tendon;
(4) Patella.

d. *Incision:* The incision in the skin, in the form of an inverted U, is begun over the medial condyle of the tibia, anterior to the tibial collateral ligament. It is carried proximally to a point one inch above the patella, then curved laterally across the quadriceps tendon, and continued distally along the anterior margin of the fibular collateral ligament to end over the lateral condyle of the tibia. The fascia, aponeurosis, and synovia are divided in the line of the skin incision. The quadriceps tendon is sectioned transversely just above the upper margin of the patella, or it is divided by a Z plastic incision. If the quadriceps tendon is to be lengthened, this may be facilitated by a longitudinal incision over the quadriceps tendon, extending upward from the apex of the U. Putti used this approach but discontinued its use, since occasionally the skin margins were found to slough at the junction of the longitudinal limb with the U (Campbell).

2. Plastic division of the tendon of the quadriceps (Coonse and Adams).
   a. *Indications:*
      (1) Complete exploration of the joint;
      (2) Synovectomy;
      (3) Arthroplasty;
      (4) Treatment of fractures of the lower end of the femur.
   b. *Position of the patient:* The position of the patient is the same as for the parapatellar approach.
   c. *Landmarks:*
      (1) Condyles of the femur;
      (2) Quadriceps;
      (3) Patella.
   d. *Incision:* The quadriceps tendon, the patella, the infrapatellar tendon, and the aponeurosis of the vastus medialis are exposed by a curved medial parapatellar incision. An inverted Y-shaped incision is made in the quadriceps tendon and aponeurosis of the vasti muscles (Fig. 11). The stem of the Y lies over the quadriceps and the two prongs extend on either side of the patella. The patella is then turned downward with exposure of the joint. Upon closure of the divided quadriceps tendon and aponeurosis, the knee can be bent to a right angle without undue tension, if sutures of sufficient strength are used. The writers have had but one experience with this operation. A good exposure to the anterior compartment of the knee joint was obtained.

D. *Incisions Which Divide the Tendon of the Patella Transversely*

1. The U-shaped incision with division of the patellar tendon (Textor).
   a. *Indications:*
      (1) Excision of the knee in extensive destruction of the joint from disease or injury;
      (2) Drainage of badly infected joints in cases of compound fractures.
   b. *Position of the patient:* The position of the patient is the same as that for parapatellar incisions.
   c. *Landmarks:*
      (1) Condyles of the femur;
      (2) Patella;
      (3) Patellar tendon;
      (4) Tubercle of the tibia.
   d. *Incision:* The skin incision is started over the prominent part of the medial femoral condyle just below the insertion of the tendon of the adductor magnus. From here it is continued downward in a gentle curve to pass just below the insertion of the patellar tendon into the tibial tubercle, and then upward and outward to the most prominent part of the lateral condyle of the femur. The incision should form a broad base which extends between the condyles of the femur. The margins of the skin are reflected sufficiently to permit division of the patellar tendon and the aponeurotic expansions of the vasti muscles. The anterior margins of the tibial collateral ligament on the medial side and the iliotibial tract on the outer side are identified and preserved. The entire flap of skin and aponeurosis, with a broad base extending between the femoral condyles, is turned upward. With flexion of the knee the following structures are exposed:
      (1) Upper end of the tibia;
      (2) Lower end of the femur;
      (3) Quadriceps pouch;
      (4) Semilunar cartilages;
      (5) The patella and the cruciate and collateral ligaments.

Excision of bone and soft tissues can be carried out as indicated in individual cases. To allow drainage in clean cases of excision of the knee, the wound is closed with inter-

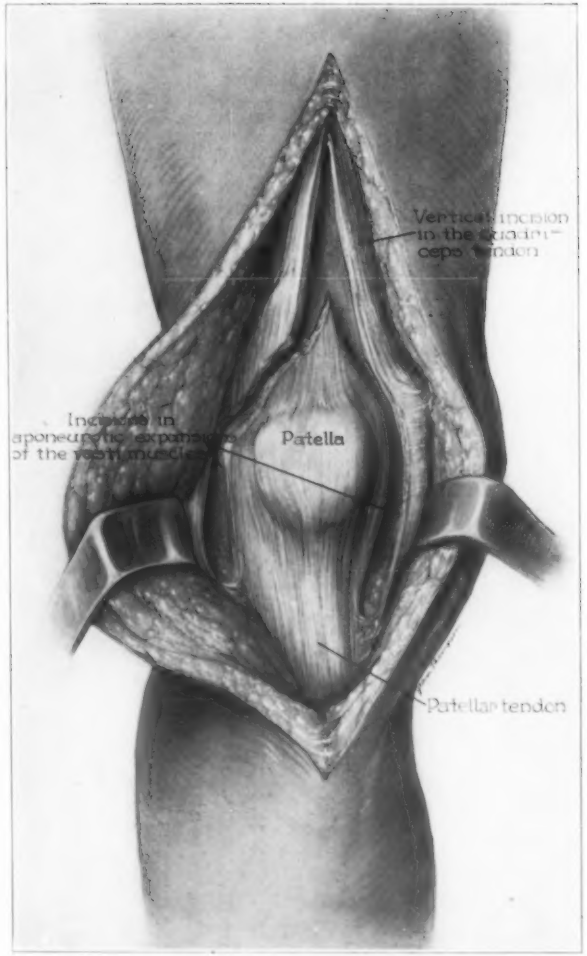

FIG. 11

Division of the quadriceps tendon after the method of Coonse and Adams.

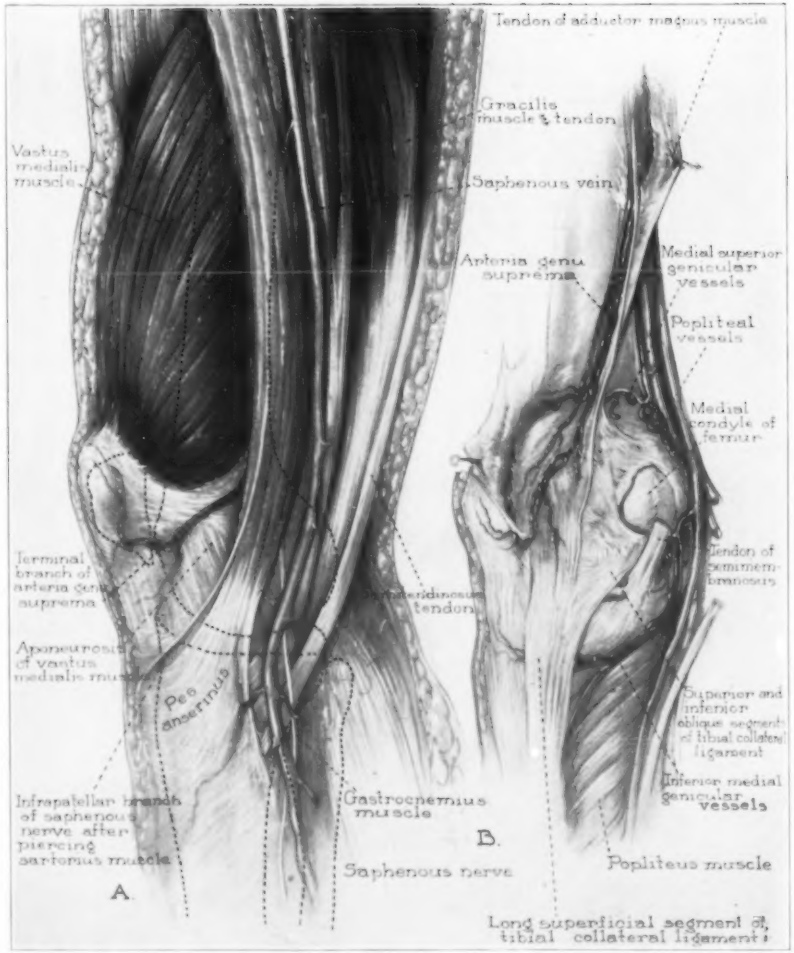

FIG. 12

Anatomical dissections of the medial aspect of the knee, showing the saphenous nerve, the saphenous vein, and the sartorius muscle.

rupted sutures only to the deep fascia and the skin. As a last recourse in severely septic joints, the patellar tendon is stitched to the skin on the anterior surface of the thigh at the junction of its upper and middle thirds.

2. The H-shaped incision of Ollier.

a. *Indications:* Ollier used this incision for excision of the knee in cases of extensive destruction of the joint. In addition, he employed posterolateral and posteromedial incisions for counter-drainage.

b. *Incision:* A transverse incision in the skin is made just below the patella, preferably with the knee in the position of 90 degrees of flexion. This incision must stay within the limits of the anterior borders of the collateral ligaments. From each end of the transverse incision, a vertical incision is made, nine centimeters in length, seven of which lie above the transverse incision. The joint is entered by cutting the patellar tendon. Counter-incisions lie anterior to the biceps tendon on the outside and to the sartorius and gracilis tendons on the medial side of the joint. The writers do not advocate the use of this incision.

II. *Approaches to the Medial Aspect of the Knee Joint*

Surgical Anatomy: The important structures on the medial aspect of the knee joint are: (1) the tibial collateral ligament, (2) the internal intermuscular septum, (3) the tendons of the sartorius, gracilis, and semitendinosus, (4) the bursae in relation to the tibial collateral ligament, (5) the saphenous vein, the saphenous nerve, the saphenous branch of the arteria genus suprema, and (6) the two branches of the medial femoral cutaneous nerves (Fig. 12, *A*).

The tibial collateral ligament is a far more extensive structure than usually described in texts on anatomy or surgery. It may be divided into four segments. The anterior superficial portion is the part which extends as a flat band, approximately four inches in length and one-half an inch in width, and is attached to the ovoid area in the region of the medial epicondyle of the femur. The distal attachment is almost one inch in length on the medial surface of the tibia, and lies about one and one-half inches below the line of the knee joint. The deep anterior portion of the ligament lies beneath the superficial part with which it is intimately blended. It consists of short fibers which bridge the joint from the femoral epicondyle to the area just below the margin of the inner condyle of the tibia. The posterosuperior, oblique portion extends from the posterior part of the femoral attachment downward and backward to the margin of the tibial condyle. The tibial attachment is extensive, and reaches to the posterior limit of the condylar margin. This part gives additional anchorage to the semilunar cartilage. The posterosuperior and posteroinferior, oblique portions of the ligament blend with the posteromedial portion of the joint capsule, forming a hemispherical pouch. This pouch is lax in flexion of the knee, but in extension it becomes tense as it encloses the posterior part of the medial femoral condyle. The existence of this arrangement should be especially emphasized. Grasping in full extension the prominent posterior part of the medial femoral condyle in an accurately fitting half bucket, it is a major factor in stabilizing the knee in this position (Fig. 12, *B*).

The intermuscular septum on the medial aspect of the thigh extends from the fascia lata inward to be attached to the linea aspera. It blends intimately with the tendon of the adductor magnus which inserts into the adductor tubercle of the femur. This membrane separates the vastus medialis in front from the adductor magnus and adductor longus behind. It forms the line of separation between the popliteal space and the anterior compartment of the knee. The tendons of the sartorius, gracilis, and semitendinosus embrace the posteromedial aspect of the medial femoral condyle, and, as they pass to their insertions in the proximal part of the anteromedial surface of the upper part of the tibia, they are separated from each other by a bursa. The tendon of the sartorius lies superficial and anterior to the tendons of the gracilis and semitendinosus, while all three span the inferior

portion of the tibial collateral ligament. The internal saphenous vein passes across the posterior part of the medial aspect of the knee, lying upon the tendon and muscle belly of the sartorius. The medial cutaneous nerve of the thigh, a branch of the femoral nerve, is found in two branches in this region. The anterior branch crosses the sartorius muscle and makes its appearance through the fascia lata in the distal part of the thigh, a short distance in front of the great saphenous vein. The posterior branch runs distally along the posterior border of the sartorius, pierces the deep fascia on the medial side of the knee, and comes to rest behind this muscle and the saphenous nerve. The saphenous nerve is the longest branch of the femoral nerve. It emerges from the lower end of Hunter's canal by passing beneath the fibrous expansion which stretches between the vastus medialis and the adductor muscles. It is accompanied by the saphenous branch of the arteria genus suprema. As it emerges from under cover of the sartorius muscle, it penetrates the deep fascia and gives off its infrapatellar branch, which pierces the sartorius and appears on the surface of the fascia lata on the medial part of the knee. Here it can be rolled over the anteromedial surface of the tibia about one-third of an inch below the joint line.

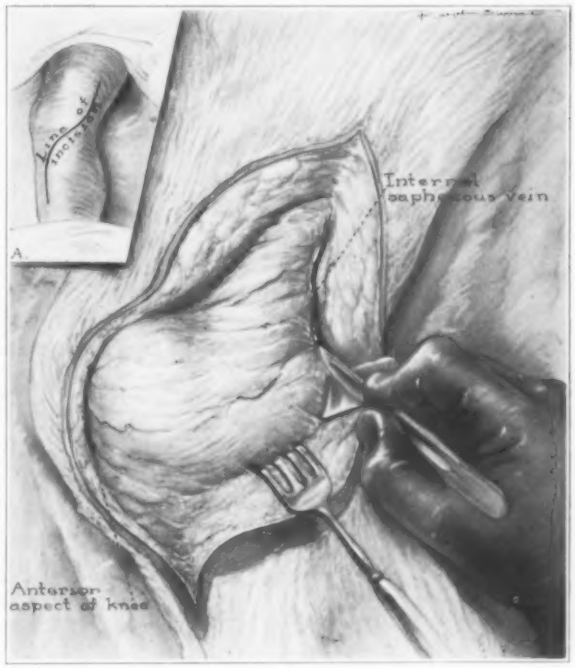

FIG. 13
The S-shaped incision on the medial aspect of the knee.

In this region the superomedial and inferomedial genicular vessels pass forward on the femur and the tibia deep to the tibial collateral ligament to join in the anastomosis formed about the anterior surface of the knee joint.

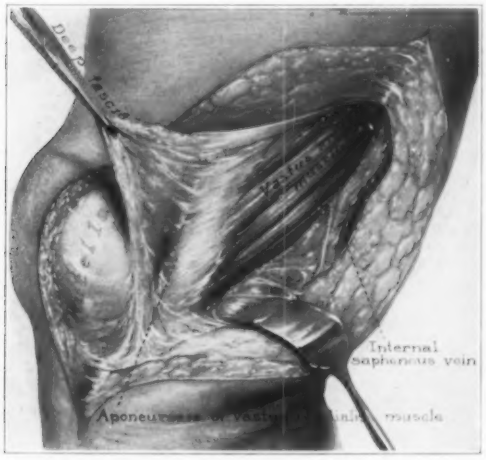

FIG. 14
The S-shaped incision with reflection of the fascia lata.

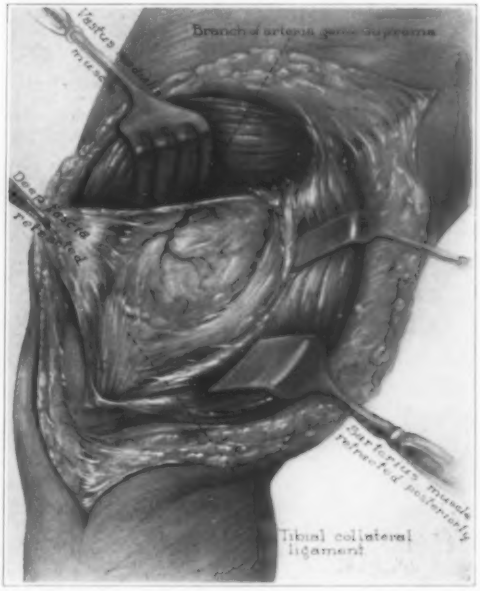

FIG. 15
The S-shaped incision with retraction of the muscles and exposure of tibial collateral ligament.

A. *The S-Shaped Incision*

1. *Indications:*
   a. Rupture of the tibial collateral ligament, especially when accompanied by injury to the anterior cruciate ligament and the internal semilunar cartilage (medial meniscus).
   b. Repair of neglected tears of the tibial collateral ligament, which requires the use of the medial hamstring tendons.
2. *Position of the patient:* The knee is supported on a narrow sandbag well above the level of the opposite leg in a position of from 15 to 20 degrees of flexion and in slight external rotation.
3. *Landmarks:*
   a. Adductor tubercle of the femur;
   b. Medial hamstring muscles;
   c. Condyle of the tibia;
   d. Joint line;
   e. Tibial tubercle.
4. *Incision:* A curvilinear incision of the skin and subcutaneous tissue is made, beginning two inches above the adductor tubercle on the posteromedial aspect of the joint, directly over the tendons of the sartorius and gracilis. It follows the course of these tendons to the level of the joint, where it is then curved gently forward along its margin to the anterior border of the upper end of the tibia. Here it is turned downward again to end just below the tibial tubercle. The skin and subcutaneous tissue are reflected upward and downward from the surface of the deep fascia (Fig. 13). The deep fascia is then incised in a vertical direction from the adductor tubercle to the medial surface of the upper end of the tibia (Fig. 14). The structures which are identified are the insertion of the adductor magnus into the adductor tubercle, and the long superficial segment of the tibial collateral ligament passing to the medial surface of the upper end of the tibia (Fig. 15). The tendons of the sartorius, gracilis, and semitendinosus are reflected posteriorly to expose the oblique segments of the tibial collateral ligament and the tendinous insertion of the semimembranosus into the posterosuperior aspect of the upper end of the tibia. Posterior to the sartorius muscle, the saphenous nerve and the posterior division of the medial femoral cutaneous nerve are seen. Inferiorly, the infrapatellar branch of the saphenous nerve passes through the sartorius, and lies on the deep fascia one-fourth of an inch below the medial margin of the tibia.

Anterior to the long superficial segment of the tibial collateral ligament, the aponeurosis and synovial membrane are incised to expose the anterior compartment of the joint. The anterior cruciate ligament and the anterior portion of the semilunar cartilage (medial meniscus) are then identified. An incision is made through the oblique segments of the tibial collateral ligament to expose the posterior extremity of the internal semilunar cartilage (medial meniscus). In late operations for the repair of the tibial collateral ligament, particularly where its posterior oblique segments have been torn, or where the tendons of the gracilis or semitendinosus are to be used to reinforce the inner aspect of the joint, the sartorius muscle is retracted anteriorly, instead of posteriorly (Fig. 16). This makes it imperative to identify the saphenous nerve and its infrapatellar branch. Unless the dissection is carried deep to the fascia lata, it is best to expose the saphenous vein, which is generally accompanied by the anterior branch of the medial cutaneous nerve of the thigh.

Structures which are made accessible by this curved incision are all parts of the tibial collateral ligament, the medial hamstring muscles, including the sartorius and gracilis, the entire internal semilunar cartilage (medial meniscus), the anterior cruciate ligament, the infrapatellar fat pad, and the medial margin of the ligamentum mucosum.

The wound is closed with interrupted sutures to the deep fascia, to the fibrous aponeurosis, and to the skin.

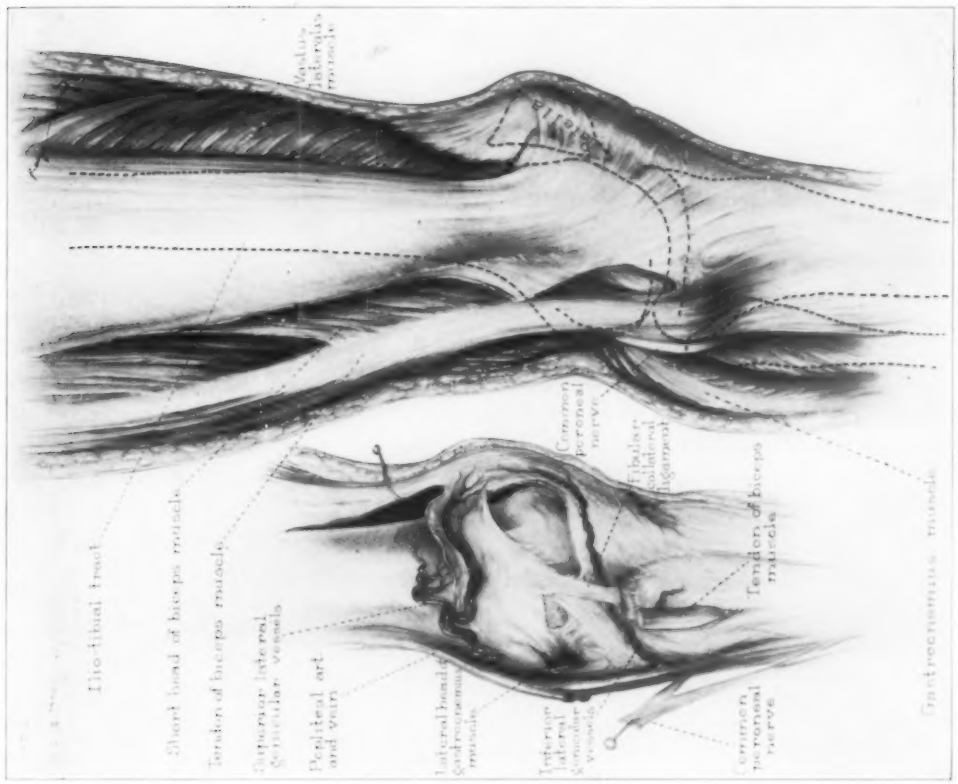

FIG. 17
Anatomical dissections of the lateral aspect of the knee.

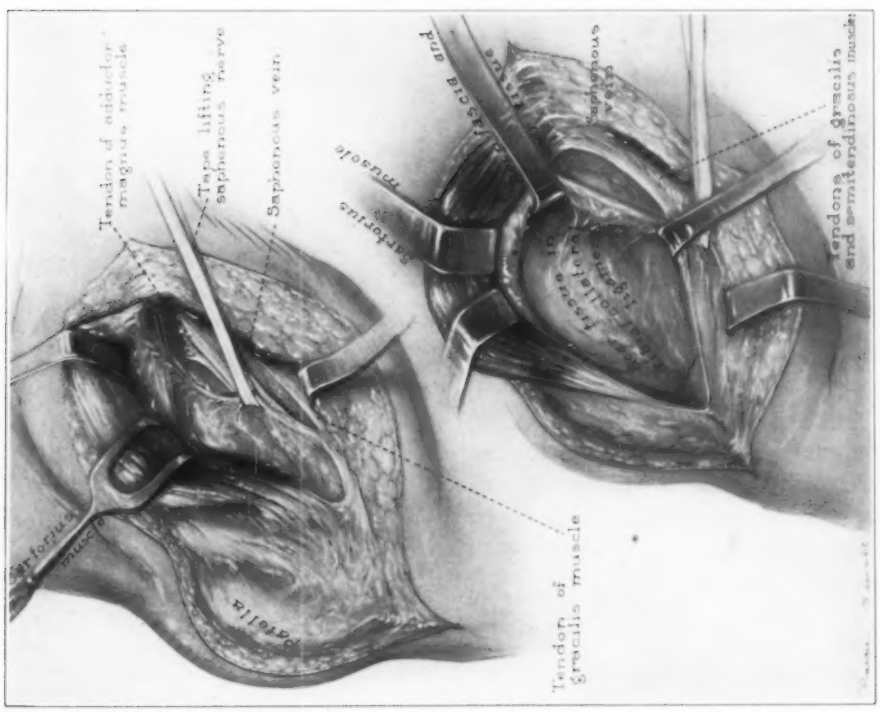

FIG. 16
The medial approach, showing an old tear of the tibial collateral ligament. In this case the sartorius was retracted anteriorly, rather than posteriorly, after exposure of the saphenous vein and the saphenous nerve.

B. *The Straight or Curved Incision*

1. A straight or simple curved incision made in a downward direction from the adductor tubercle may be used, if a more limited exposure is sufficient.

III. *Approaches to the Lateral Aspect of the Knee Joint*

Surgical Anatomy: The important structures on this aspect of the joint are, from before backward, the iliotibial tract, the lateral intermuscular septum, the fibular collateral ligament, the tendon of insertion of the popliteus muscle, the tendon of insertion of the biceps, and the common peroneal nerve (Fig. 17).

The iliotibial tract is in reality the fibrous tendon of the tensor fasciae femoris, which embraces the lateral condyle of the femur (Saunders), and is inserted into the upper margin of the external tuberosity of the tibia. The lateral intermuscular septum passes inward from the tract to insert into the linea aspera. It separates the vastus lateralis muscle in front from the short head of the biceps muscle behind. As in the case of the medial intermuscular septum, it separates the anterior compartment of the knee and the popliteal space on the lateral aspect of the joint. The fibular collateral ligament is attached above to the lateral epicondyle of the femur and below to the head of the fibula. The tendon of the biceps muscle is inserted into the head of the fibula, dividing into two parts to enclose the ligament from which it is often separated by a bursa. Beneath the fibular collateral ligament, the tendon of the popliteus muscle is inserted into the lateral epicondyle of the femur. It is surrounded by a synovial sheath which is an extension of the synovial membrane of the knee joint. A short distance posterior to the fibular collateral ligament, a thick capsular segment passes from the head of the fibula to the condyle of the femur; this is sometimes termed the short fibular collateral or arcuate ligament. In this region the superior lateral genicular artery passes beneath the tendon of the biceps, pierces the lateral intermuscular septum above the femoral attachment of the fibular collateral ligament, and breaks up into branches which anastomose in the substance of the vastus lateralis. The inferolateral genicular artery passes outward on the fibular head of the soleus muscle, and then beneath the fibular collateral ligament, just above its insertion into the head of the fibula.

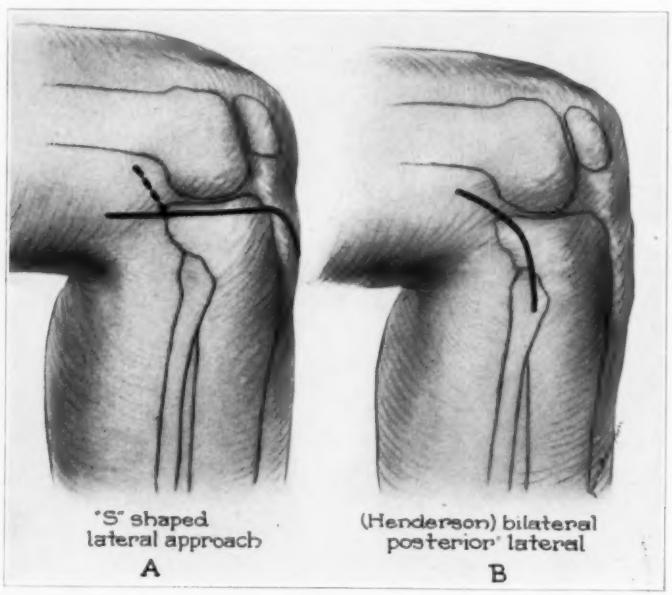

FIG. 18
Incisions on the lateral aspect of the knee.

A. *The S-Shaped Incision* (Fig. 18)

1. *Indications:*
   a. Derangements of the fibular collateral ligament;
   b. Open reduction of fractures of the lower end of the femur;
   c. Cysts of the external semilunar cartilage (lateral meniscus).
2. *Position of the patient:* The leg may be placed on a sandbag above the level of its fellow, or the knee may be flexed at right angles over the edge of the

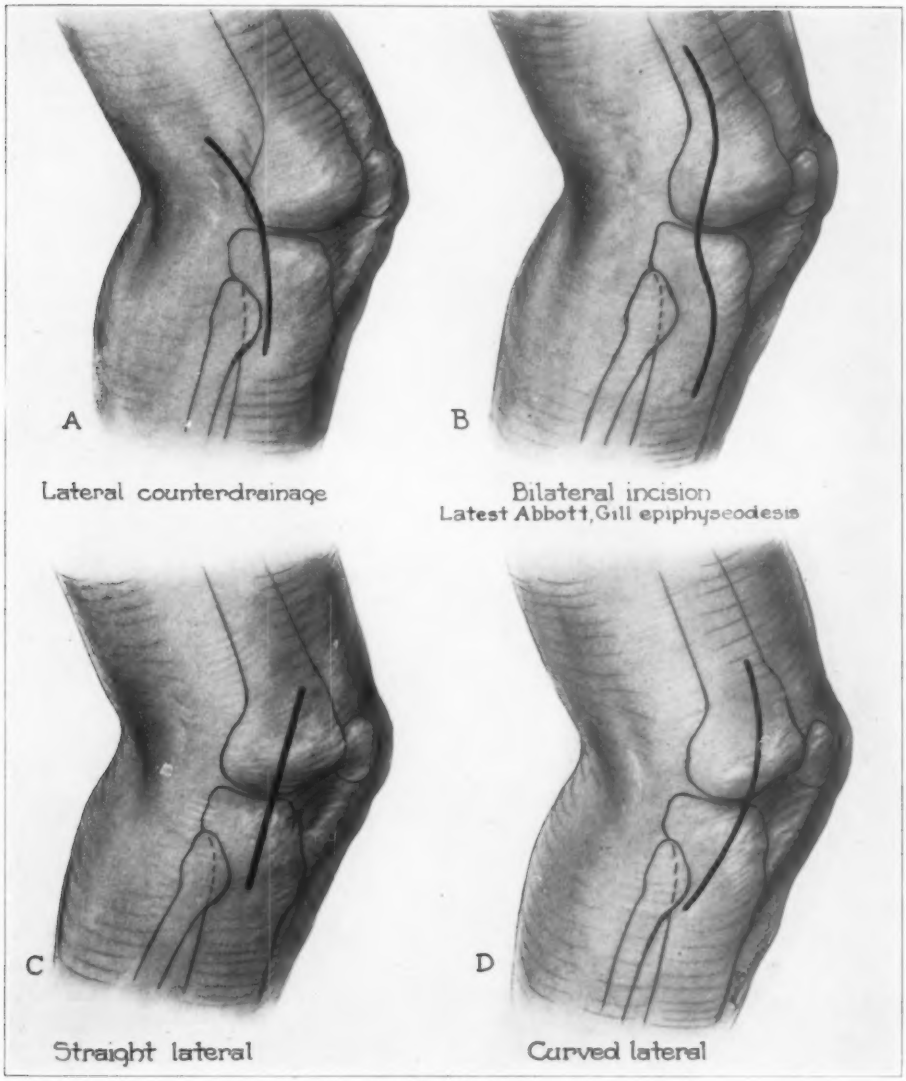

FIG. 19
Incisions on the lateral aspect of the knee.

table with the calf supported so that the posterolateral aspect of the knee is free. The writers prefer the Trendelenburg position, since its helps maintain the position of the patient.

3. *Landmarks:*
   a. Lateral condyle of the femur;
   b. Head of the fibula;
   c. Biceps tendon;
   d. Iliotibial band;
   e. Lateral aspect of the joint line;
   f. Patella;
   g. Infrapatellar tendon.

4. *Incision:* The incision is similar to the incision for complete exposure of the medial aspect of the joint. It is begun about two inches above the lateral condyle of the femur, lying well posteriorly in the sulcus between the tendon of the biceps muscle and the iliotibial tract. It is continued directly forward, following the lateral margin of the upper

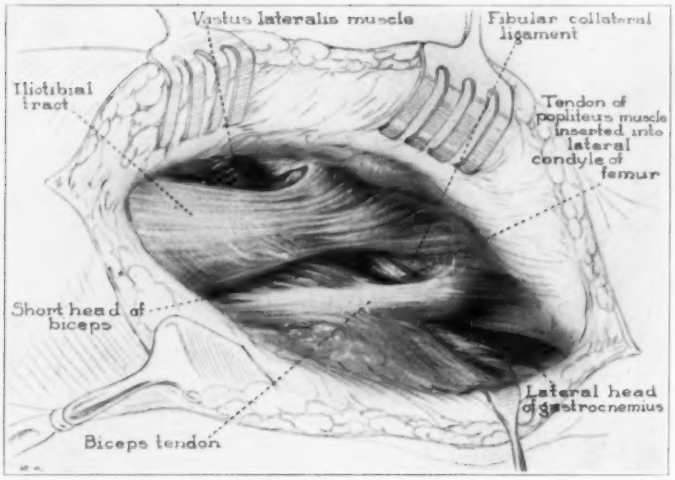
Vastus lateralis muscle
Fibular collateral ligament
Iliotibial tract
Tendon of popliteus muscle inserted into lateral condyle of femur
Short head of biceps
Lateral head of gastrocnemius
Biceps tendon

FIG. 20

The structures which are exposed through the curved lateral incision.

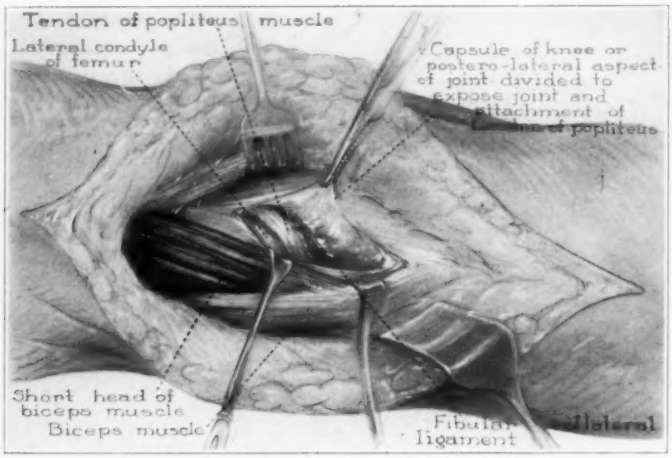
Tendon of popliteus muscle
Lateral condyle of femur
Capsule of knee or postero-lateral aspect of joint divided to expose joint and attachment of tendon of popliteus
Short head of biceps muscle
Biceps muscle
Fibular ligament
Lateral

FIG. 21

The curved lateral incision with exposure of the deep structures and the insertion of the tendon of the popliteus muscle.

end of the tibia, and is then curved downward to the tibial tubercle. The structures exposed are the biceps tendon, the posterolateral part of the joint capsule, the fibular collateral ligament, and the lower part of the iliotibial tract (Fig. 20). The peroneal nerve is found lying just behind the biceps tendon. From here it can be traced to the lateral aspect of the neck of the fibula. The biceps tendon is followed to its insertion into the fibula, where it will be found to bifurcate in order to enclose the fibular collateral ligament. At this stage, the ligament is followed upward to its attachment into the epicondyle of the femur. Lying deep and slightly posterior to the fibular collateral ligament, the tendon of the popliteus is exposed (Fig. 21). If the anterior aspect of the joint is to be entered, the anterior portion of the fibrous aponeurosis of the vastus lateralis and the synovial membrane are excised in a direction downward and forward. The anterior half of the external semilunar cartilage (lateral meniscus) is readily exposed without division of the tendinous fibers of the iliotibial tract. By this incision an excellent approach is obtained to the fibular collateral ligament, the biceps tendon, the common peroneal nerve, the posterior joint line, the iliotibial tract, the entire semilunar cartilage (lateral meniscus), the lateral aspect of the fat pad, and the infrapatellar tendon.

B. *The Straight or Curved Incision* (Fig. 19)

As in the case of the medial aspect of the knee, a straight or curved incision may be employed for a limited exposure.

IV. *Exposure of the Semilunar Cartilages (the Menisci)*

Surgical Anatomy: On the anteromedial aspect a triangular space is formed, the boundaries of which are the patellar tendon in front, the condyle of the femur and the anterior margin of the tibial collateral ligament behind, and the upper margin of the tibia below. A similar space is formed on the anterolateral aspect of the knee joint, bounded in front by the patellar ligament, behind by the condyle of the femur and the fibular collateral ligament, and below by the margin of the tibia.

A. *For Partial Removal of the Internal Semilunar Cartilage (Medial Meniscus)*

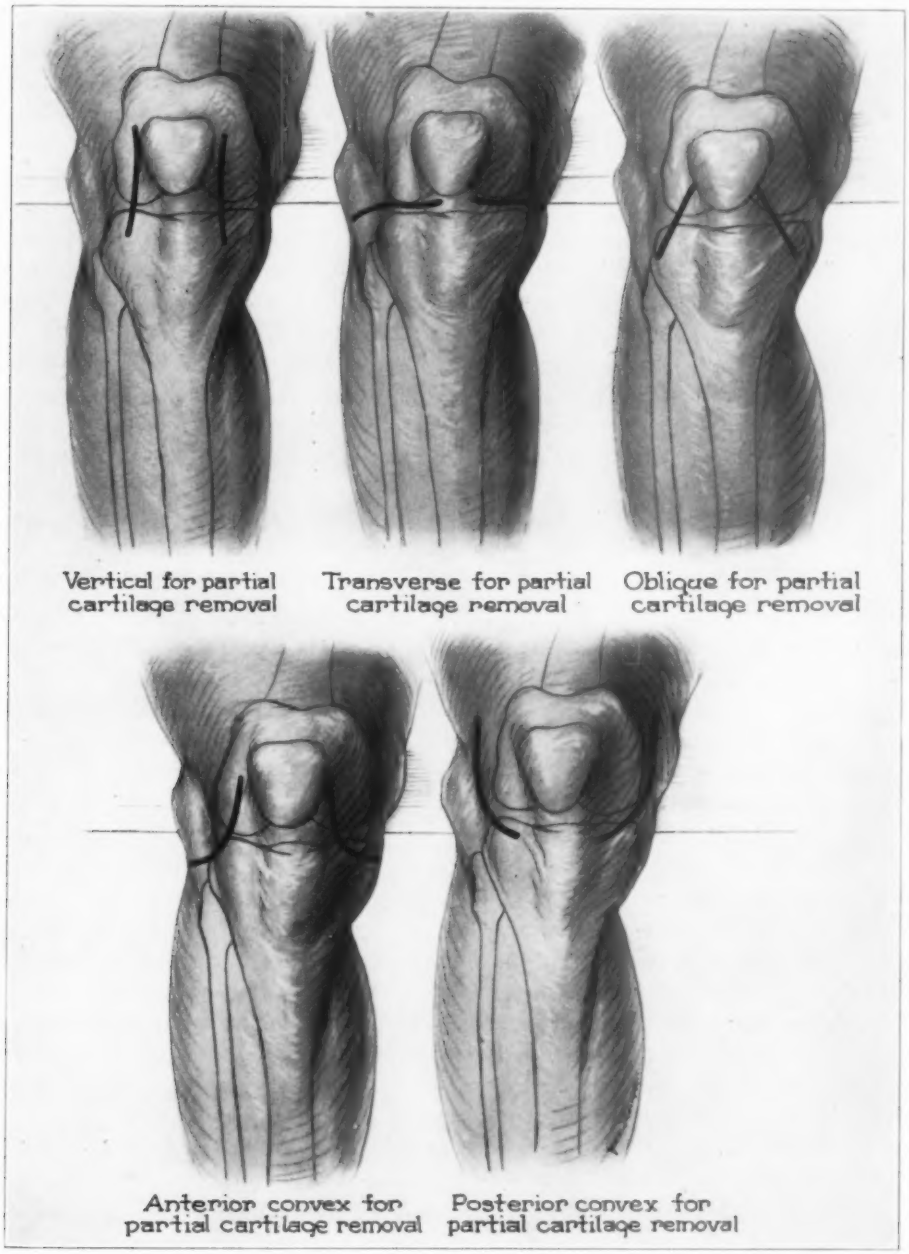
Vertical for partial cartilage removal
Transverse for partial cartilage removal
Oblique for partial cartilage removal
Anterior convex for partial cartilage removal
Posterior convex for partial cartilage removal

FIG. 22

The anterior incisions for partial removal of the semilunar cartilages.

1. *Position of the patient:* The patient is in a slightly Trendelenburg position, with the knee flexed to 90 degrees over the end of the table.
2. *Landmarks:*
   a. Medial condyle of the femur;
   b. Tibial tubercle;
   c. Patellar tendon;
   d. Patella;
   e. Anteromedial joint line.
3. *Incision:* The incisions which may be used for partial removal of the internal semilunar cartilage are the curved incision with an anterior convexity (Jones), the curved

incision with a posterior convexity (Fisher), the oblique or nearly transverse incision, and the vertical incision (Fig. 22). These incisions are made in order to expose the joint adequately, and they vary in their directions according to the decision of the operating surgeon. The structures which are exposed are the infrapatellar fat pad, the ligamentum mucosum, the anterior portion of the origin of the anterior cruciate ligament, and the anterior two-thirds of the semilunar cartilage (medial meniscus).

The curved skin incision, with an anterior convexity, is made on the anterior surface of the medial condyle of the femur, on a level with the lower portion of the patella. It is curved gently downward to the level of the tibia, and backward along its upper margin for a distance of three-quarters of an inch. In the subcutaneous tissue, the infrapatellar branch of the saphenous nerve is identified one-half an inch below the medial margin of the tibia. It is freed and retracted, with exposure of the aponeurosis of the vastus medialis. This aponeurosis and synovial membrane are incised, and the joint is entered.

B. *For Complete Removal of the Internal Semilunar Cartilage (Medial Meniscus)*

1. *Indications:*
   a. Derangements of the cartilage, especially when the posterior portion is damaged;
   b. Cysts of the semilunar cartilage;
   c. Limited exposure of the tibial collateral ligament.
2. *Position of the patient:* The patient is supine in a partial Trendelenburg position, with the knee flexed 90 degrees over the end of the table. The calf of the leg is supported from behind, to free completely the posteromedial aspect of the knee.
3. *Landmarks:*
   a. Medial condyle of the femur;
   b. Medial tibial tubercle;
   c. Patellar tendon;
   d. Patella;
   e. Anteromedial joint line.
4. *Incision:* The descriptions of the following incisions are taken from published articles by Cave, Bosworth, and Fisher (Fig. 23).

a. *The Cave incision:* The skin incision is begun three-eighths of an inch above and behind the internal femoral epicondyle. It is then curved downward to the joint line, and then forward one-quarter of an inch below the joint line to the patellar tendon. The flap formed of skin and subcutaneous tissue is dissected upward to expose the vastus aponeurotic expansion and the tibial collateral ligament. The anterior part of the joint capsule is incised just in front of the tibial collateral ligament, and the synovia is opened through the same incision. The posterior capsule of the joint is then opened behind the long superficial segment of the tibial collateral ligament. Therefore, two openings are made into the joint,—one in front of, and one behind the tibial collateral ligament. The accessible structures are the internal semilunar cartilage (medial meniscus) and the medial portion of the fat pad (Fig. 24).

Closure is effected by interrupted sutures to the fibrous aponeurosis and the fibrous capsule lying, respectively, in front of and behind the tibial collateral ligament.

b. *The incision of Bosworth:* An oblique incision, slanting upward and slightly backward, is made over the anteromedial aspect of the joint. The skin and subcutaneous tissues are reflected forward, and the capsule is opened by a vertical incision at the usual point anteriorly, in line with its fibers. The synovial membrane above the meniscus is opened between two pairs of forceps, care being taken not to cut the articular surface of the underlying femoral condyle. The small synovial pouch below the meniscus should be opened in a similar fashion. By means of curved scissors, one blade of which is placed

above and the other below the meniscus, the anterior end of the meniscus can be freed from the synovial membrane and the coronary ligaments. The knee is then flexed, and the skin and subcutaneous tissue are dissected backward to the collateral ligament, close to the capsule of the joint. This capsule is opened along the posterolateral margin of the femoral condyle behind the collateral ligament by a vertical incision in line with its fibers. The anterior portion of the meniscus is then passed backward under the collateral ligament, and its posterior third can be visualized extending into the back of the joint. The posterior third is freed as far as the posterior tibial spine. When the knee is straightened, the posterior incision will be found to close tightly. The anterior incision of the capsule is closed with a few interrupted sutures.

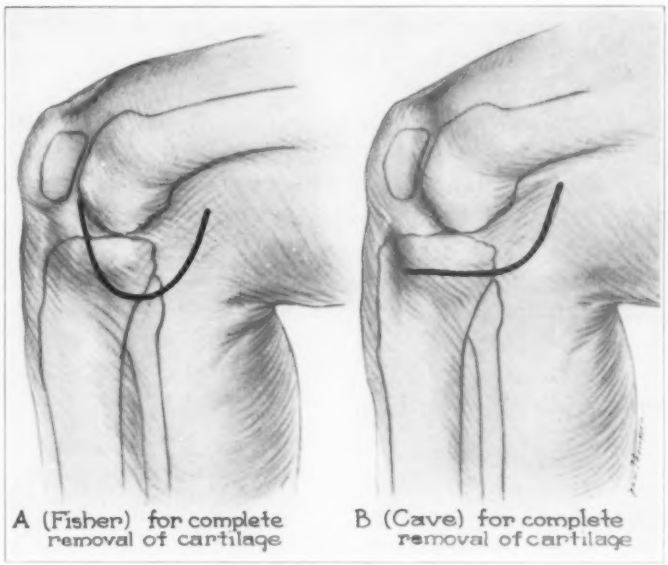

FIG. 23
Two incisions for complete removal of the semilunar cartilages.

In this approach the operating surgeon uses the extended and flexed positions of the knee, respectively, to facilitate exposure of the anteromedial and posteromedial portions of the joint.

c. *The incision of Fisher:* A curved incision is made over the anteromedial aspect of the joint. It is begun above at a point midway between the patellar ligament and the anterior border of the tibial collateral ligament at the level of the apex of the patella. It ends below and behind, slightly inferior to the internal margin of the upper part of the tibia at the anterior border of the tibial collateral ligament. The infrapatellar branch of the internal saphenous nerve should be identified and retracted. The capsule and synovial

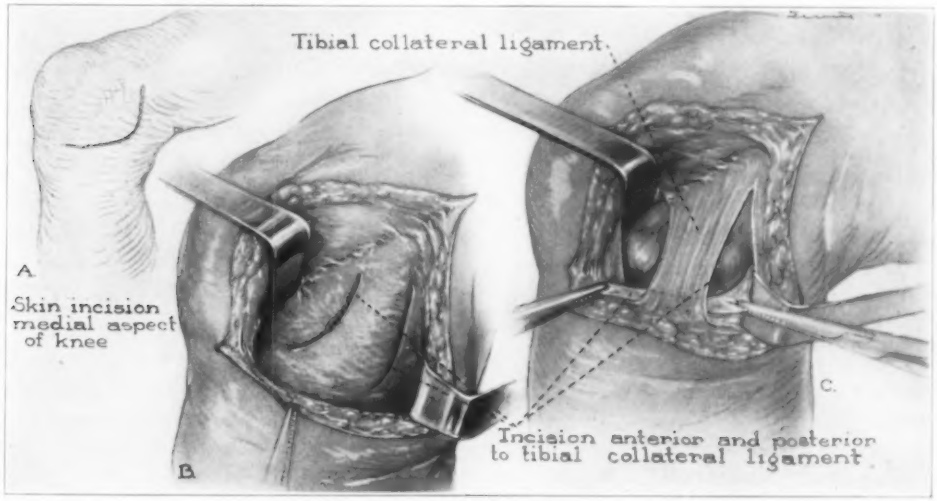

FIG. 24
The Cave incision for removal of the internal semilunar cartilage (Redrawn from Cave).

membrane are next divided in line with the skin incision, but preferably a little nearer to the tibial collateral ligament, and the joint is thus opened. The semilunar cartilage is examined, and, if found necessary, the second portion of the incision is made as follows: The anterolateral incision is temporarily closed with gauze, and the skin incision is continued over the inner margin of the joint slightly below the joint level; the incision is then carried upward and backward over the inner aspect of the posterior compartment of the joint. The completed incision is thus semicircular in outline, and enables a flap of skin and subcutaneous tissue to be raised. A curved incision is next made in that part of the capsule lying behind the tibial collateral ligament, and after the synovial lining is divided, a good exposure of the posterior part of the joint and the posterior end of the semilunar cartilage is obtained.

Similar incisions are used for partial and complete exposure of the external semilunar cartilage (lateral meniscus).

V. *Bilateral Incisions*

Surgical Anatomy: The surgical landmarks on the lateral aspect of the joint, which are utilized in all four of the bilateral incisions, are as follows:

1. Lateral epicondyle of the femur;
2. Head of the fibula;
3. Lateral margin of the upper part of the tibia;
4. Biceps tendon;
5. Lateral intermuscular septum;
6. Fibular collateral ligament;
7. Iliotibial tract.

On the medial aspect, the important landmarks are:

1. Adductor tubercle of the femur;
2. Tendons of the sartorius, gracilis, and semitendinosus;
3. Medial condyle of the femur;
4. Medial intermuscular septum;
5. Tibial collateral ligament.

On the lateral aspect of the knee, the lateral intermuscular septum and the fibular collateral ligament form the line of separation of the anterior compartment of the knee from the popliteal surface of the femur above and from the posterior compartment of the knee below. On the medial aspect of the knee, the medial intermuscular septum and the posterior margin of the tibial collateral ligament separate the anterior compartment of the joint from the popliteal surface of the femur and the posterior compartment of the knee.

A. *Exposure of the Popliteal Face of the Femur (Henry)*

1. *Medial Approach*

a. *Position of the patient:* "Put a sand-bag three inches thick under the buttock on the sound side, as he lies recumbent. Place the foot of the affected limb upon the opposite shin, as near the knee as possible."

b. *Incision:* "Make a longitudinal 8-inch cut which follows the bend of the limb, through skin and superficial fascia only, so that two inches of the cut lie distal to the adductor tubercle and six inches are proximal to it. Dissect back the lower lip of the wound for about an inch. Expose the sartorius just proximal to the level of the adductor tubercle, and free the muscle by dividing the deep fascia along its anterior edge. To do this, slip one blade of the blunt-nosed scissors under the fascia, and thus avoid injuring the synovial membrane of the knee, which is subjacent to the sartorius when the joint is flexed.

"The free sartorius falls back and exposes the tendon of the adductor magnus. The saphenous nerve leaves Hunter's canal in front of the tendon, and travels in this region deep to the sartorius. Sometimes the muscle carries the nerve with it upon its deep aspect; sometimes the nerve is left like a lax string across the bend of the limb. It is accompanied by a superficial branch of the anastomotica magna [arteria genus suprema, B.N.A.], some twigs of which may require division. The internal saphenous vein lies superficial to the sartorius, and is not seen if the skin incision has been properly placed.

"Pick up the thin fascia immediately behind the adductor tendon. Open it as one does the peritoneum. Thrust in the forefinger, keeping its back against the tendon till the nail strikes the bone at the middle of its

popliteal face. The popliteal vessels lie at some distance—often an inch—behind this surface; bend the forefinger and gently hook them up. Work the finger along the bone and mobilize the vessels—proximally as far as the opening in the adductor magnus, and distally to the notch between the condyles of the femur. An assistant protects the vessels with a wide retractor, and draws them back with the sartorius. He draws forward the adductor tendon and the part of the vastus muscle which arises from it.

"As the popliteal vessels are drawn back, the inconstant twigs which they send to the bone appear like strings across the wound; they are easily caught and divided, and the popliteal face of the femur is laid bare.

"The internal and external popliteal nerves [the tibial and common peroneal, B.N.A.] are not seen; they lie in that part of the wound which is next to the table, and are sufficiently remote from the bone to be out of harm's way."

2. *Lateral Approach*

a. *Position of the patient:* "The patient lies on the sound side with the sound limb extended. Place the knee of the affected side just in front of the other knee, so that the heel on the affected side rests upon the other shin; this tilts the popliteal surface to a convenient angle."

b. *Incision:* "Make a longitudinal 6-inch cut, through skin and superficial fascia only, along the hinder edge of the iliotibial tract two finger-breadths in front of the biceps tendon. The incision follows the bend of the limb and ends at the head of the fibula. Pick up the deep fascia immediately behind the iliotibial tract; divide it in the line of the skin incision, using blunt-nosed scissors to avoid injuring the synovia of the knee. At a point just proximal to the condyle, pass the index finger into the plane of cleavage between the biceps belly and the intermuscular septum. Work the finger up along the septum, and gently separate the few and slender fleshy attachments of the biceps from its posterior face. As this is done, the finger will meet with two or three resistant strands—posterior branches which the perforating vessels give off before they pierce the intermuscular septum. Divide and tie these branches. Then, keeping the back of the forefinger against the edge of the iliotibial tract, pass it into the popliteal fossa until the finger-tip touches the bone at the middle of the popliteal face. Gently hook up the popliteal vessels and mobilize them with the finger. Retract them back, together with the posterior wall of the wound.

"The popliteal aspect of the bone is now completely exposed. The two great nerves of the space—the internal and external popliteal [tibial and common peroneal, B.N.A.]—are not usually seen unless they are sought. They lie on a plane slightly behind that of the vessels, and the short head of the biceps shelters them as they skirt its medial edge."

B. *The Approach for Epiphyseodesis*

Position of the patient: The knee is held by sandbags in about 30 degrees of flexion, since this position relaxes the hamstring muscles, and the bony landmarks can be readily palpated. If the lower femoral and the upper tibial epiphyses are to be fused at one operation, they are exposed through long, curved incisions over the internal and the external aspects of the knee joint. If either the lower femoral or the upper tibial epiphysis is to be fused alone, then the upper or lower halves respectively of the incisions are employed.

1. Lateral aspect of the knee: The incision in the skin begins about two and one-half inches above the lateral condyle of the femur, directly over the interval between the biceps tendon and the tractus iliotibialis. It curves downward and backward to the head of the fibula, and then gently forward on the lateral surface of the upper part of the tibia. The lateral intermuscular septum is exposed in the upper part of the wound, and traced to its attachment to the linea aspera; this frees some of the fibers of origin of the vastus lateralis from its anterior surface. The muscle is retracted forward to expose the lateral surface of the femur and its junction with the lateral condyle. This junction marks the site of the epiphyseal cartilage. Immediately below, the capsule of the knee joint should be identified. The superolateral genicular vessels appear directly on the bone, passing forward after piercing the septum, and are distributed to the fibers of the vastus lateralis. For good exposure of the epiphyseal line of the femur, they may require ligation.

The exposure of the upper fibular and tibial epiphyseal cartilages is rendered safe by dissection of the common peroneal nerve. This structure is found by incision of the deep fascia, directly posterior and internal to the tendon of the biceps muscle. From here it can be traced downward, freed at the neck of the fibula, and retracted posteriorly. An incision over the upper and medial portions of the head of the fibula readily exposes its epiphyseal cartilage. The cartilage plate of the tibia is revealed by downward reflection, with a periosteal elevator, of the upper fibers of origin of the extensor muscles from the

arcuate line. The line of cartilage is shown by the removal of a thin section of bone one-half to three-fourths of an inch (1.3 to 1.9 centimeters) below the margin of the joint.

2. Medial aspect of the knee joint

a. *Incision:* An incision, five inches in length, is made with its center approximately at the level of the adductor tubercle. In its upper part, it passes over the inner surface of the internal condyle of the femur; and in the lower part, it curves gently forward to follow the anterior margin of the tendon of the sartorius. By incision of the deep fascia, the anterior surface of the internal intermuscular septum is identified and traced to its attachment to the linea aspera. The vastus medialis, after separation of a few fibers of origin from the septum, is retracted anteriorly, exposing an interval, the floor of which is the internal surface of the femur and its junction with the flare of the adductor tubercle. The anterior and posterior walls of this space are formed, respectively, by the vastus medialis muscle and the tendinous portion of the adductor magnus. In the distal portion of this space lies the epiphyseal cartilage, overlapped by the attachment of the capsule and the reflected synovial membrane of the knee joint. The genicular vessels are ligated, and a vertical incision is made through the periosteum downward toward the epiphyseal cartilaginous plate. The periosteum, with the margin of joint capsule, is pushed downward laterally to expose the epiphyseal cartilage. This exposure is facilitated by raising a portion of cortical bone.

The upper tibial epiphysis is now exposed by incising the deep fascia along the anterior margin of the sartorius tendon. The infrapatellar branch of the saphenous nerve lies forward and need not be exposed. In the depth of the wound the anterior margin of the tibial collateral ligament is found and retracted backward. The epiphyseal cartilage is located directly in front of this ligament and from one-half to three-fourths of an inch below the upper margin of the tibia.

C. *The Posterolateral and Posteromedial Approaches (Henderson)*

Indications: Removal of loose bodies from the posterior compartment of the knee.

Position of the patient: The position of the patient is the same as that for the removal of the semilunar cartilages. The patient is placed in a modified Trendelenburg position, with the knee flexed to a right angle over the end of the table.

1. The posterolateral approach

a. *Incision:* A curved incision, from three and one-half to four inches in length, is made over the interval between the biceps tendon behind and the iliotibial tract in front. In the upper part of the interval, the external intermuscular septum is traced to the linea aspera, two inches above the lateral condyle of the femur. The lateral condyle of the femur is then exposed, with the origin of the fibular collateral ligament. Lying between the biceps tendon and the fibular collateral ligament, the tendon of the popliteus is identified. Beneath this tendon lies the lateral condyle of the femur, and, with the retraction of the tendon posteriorly, the posterolateral aspect of the knee-joint capsule is exposed. A vertical incision is made in the capsule, with exposure of the posterolateral aspect of the joint as far inward as the intercondylar notch.

2. The posteromedial approach

a. *Incision:* A curved incision with its convexity forward, three and one-half inches in length, begins at the adductor tubercle and is extended downward, following the course of the tibial collateral ligament. The structures identified after incision of the skin and subcutaneous tissues are the tibial collateral ligament and the sartorius muscle. With flexion of the knee, the sartorius is retracted posteriorly, and the oblique portion of the tibial collateral ligament is exposed and incised. The posteromedial compartment of the knee can be inspected laterally as far as the intercondylar notch.

D. *Posterior Capsulotomy in Flexion Contracture of the Knee Joint (Wilson)*

Position of the patient: The patient is supine, with the knee flexed from 20 to 30 degrees.

Incision: Vertical incisions are made on the posteromedial and posterolateral aspects of the lower end of the femur. The hamstring tendons are lengthened, and the contracted fascia is divided. A transverse incision is then made through the periosteum on the posterior surface of the lower end of the femur, and this structure, together with the origin of the capsule, is freed from the femur. The flexion contracture of the joint is thus relieved.

VI. *Approaches to the Posterior Aspect of the Knee*

Surgical Anatomy: The popliteal fossa is a diamond-shaped space, which is bounded above by the hamstring muscles and below by the converging heads of the gastrocnemius muscle. The roof of the fossa is covered by the popliteal fascia, which is a direct continuation of the fascia lata. The popliteal fascia is pierced by certain structures which are important to the surgeon as landmarks. At the lower apex of the fossa, lying quite deeply between the heads of the gastrocnemius muscle, is the posterior cutaneous nerve of the calf. After piercing the fascia, it passes upward within the fossa to become the uppermost branch of the posterior tibial nerve. As the first step in the dissection of the popliteal fossa, the posterior cutaneous nerve of the calf is identified, and serves thereafter as a guide through the popliteal fat to the underlying posterior tibial nerve. The popliteal vessels lie anterior and medial to the posterior tibial nerve. Immediately lateral to the posterior cutaneous nerve of the calf is the external saphenous vein and the posterior cutaneous nerve of the thigh. Two other nerve branches in this region which might confuse the surgeon are the lateral cutaneous nerve of the calf and the anastomotic peroneal nerve. They arise as single branches or from a parent trunk from the common peroneal nerve and pass over the lateral head of the gastrocnemius under the fascia lata. The lateral cutaneous nerve supplies the skin on the anterolateral aspect of the proximal part of the leg, while the anastomotic peroneal branch proceeds downward to join the posterior cutaneous nerve of the calf a short distance distal to the middle of the leg, forming the sural nerve. At the upper part of the fossa the common peroneal and posterior tibial nerves join to form the sciatic nerve. The popliteal artery and vein with their genicular branches lie deep in the fossa, anterior and medial to the great nerve trunks (Fig. 25).

A. *The Mid-Line Approach to the Popliteal Space*

1. *Indications:*
   a. Exposure of the sciatic nerve and its branches;
   b. Neurectomy of the popliteal nerves in spastic paralysis;
   c. Aneurysm of the popliteal vessels;
   d. Flexion contracture of the knee with contracture of the hamstrings and posterior capsule of the knee joint;
   e. Removal of loose bodies in the posterior compartment of the knee;
   f. Rupture of the posterior cruciate ligament.
2. *Position of the patient:* The patient is placed in a prone position, with slight flexion of the knee. The lower extremity is supported on a narrow sandbag which raises it above the level of the opposite leg.
3. *Landmarks:*
   a. Hamstring tendons (internal and external) particularly the semitendinosus;
   b. Heads of the gastrocnemius;
   c. Head of the fibula.
4. *Incision:* One of two incisions may be employed, — vertical or curvilinear. The curvilinear incision is preferable, because it is less likely to form a keloid. In making this incision, the principal guide is the tendon of the semitendinosus muscle, which can be felt as a cordlike structure, passing obliquely downward and inward across the posteromedial aspect of the joint. The incision is begun about three to four inches (7.5 to 10

centimeters) above the knee joint, follows the tendon of the semitendinosus downward to the level of the joint, turns laterally across its posterior aspect for a distance of about two inches (5 centimeters), and is continued downward again over the lateral head of the gastrocnemius. The skin is reflected to expose the popliteal fascia.

The first structure to be identified is the posterior cutaneous nerve of the calf, as it lies beneath the fascia rather deeply between the two heads of the gastrocnemius (Fig. 26). It is accompanied by the cutaneous branch of the popliteal vein. Lateral to this nerve, the external saphenous vein is also seen perforating the popliteal fascia to join the popliteal vein at the middle of the fossa. Still farther laterally and again deep to the fascia, the anastomotic peroneal nerve and the lateral cutaneous nerve of the calf are seen. The posterior cutaneous nerve of the calf is the clue to the dissection. Traced proximally, it joins the posterior tibial nerve as its first branch. The location of the posterior tibial nerve, so readily found by this method, enables accurate dissection through the mass of fat which occupies the popliteal fossa. It is traced downward until one can see the branches to the heads of the gastrocnemius, the plantaris, and the soleus muscles. These branches are accompanied by arteries and veins and muscular branches from the popliteal vessels. The posterior tibial nerve is then followed proximally to the apex of the fossa, where it joins the common peroneal nerve to form the sciatic. The common peroneal nerve is dissected downward along the medial border of the biceps muscle and tendon, care being taken to preserve the lateral cutaneous nerve of the calf and the anastomotic branch. As already stated, these two nerves may arise singly or from a common stem. The common peroneal nerve is followed to the head of the fibula, where it lies between the medial border of the biceps and the lateral head of the gastrocnemius (Fig. 27). The popliteal artery and vein are now exposed, lying directly anterior and medial to the posterior tibial nerve. By gently retracting the artery and vein, the superolateral and superomedial genicular vessels can be readily found. Traced outward, these vessels pass just proximal to the heads of origin of the gastrocnemius, beneath the hamstring muscles on either side. The next important step to facilitate wide exposure of the floor of the fossa is the sectioning of the tendon of origin of the medial head of the gastrocnemius (Fig. 28). This tendinous origin is freed from the femur and turned laterally to serve as a retractor for the popliteal vessels and nerves. Still greater access can be secured by ligation of one or more of the genicular vessels. If the posterolateral aspect of the joint is to be exposed, the lateral head of the gastrocnemius is dealt with in a similar fashion. With retraction of the larger vessels and nerves, the floor of the fossa is seen with the insertion of the semimembranosus into the tibia, and its fascial expansions to the oblique popliteal ligament, to the popliteal fascia, and to the tibial collateral ligament (Figs. 29 and 30).

The structures which are made accessible by the posterior mid-line approach are the posterior capsule of the knee joint, the posterior part of the semilunar cartilages (menisci), the posterior compartment of the knee, the posterior aspect of the condyles of the femur, the posterior aspect of the condyles of the tibia, and the origin of the posterior cruciate ligament.

The wound is closed by three layers of interrupted silk sutures to the capsule, to the deep fascia, and to the skin. The closure of the popliteal fascia is best effected by placing all sutures, and then drawing them taut and tying them one by one.

VII. *Approaches for Drainage of Sepsis of the Knee Joint*

Surgical Anatomy: The incisions which are used in sepsis of the knee joint are devised to drain the anterior compartment of the knee and the popliteal space. The structures which separate the anterior compartment and the popliteal space are the lateral and medial intermuscular septa, the fibular collateral ligament, and the tibial collateral ligament. If incisions are made to expose the anterior surface to the intermuscular septa, the anterior compartment of the joint is exposed. If the posterior surfaces of the septa are followed, the

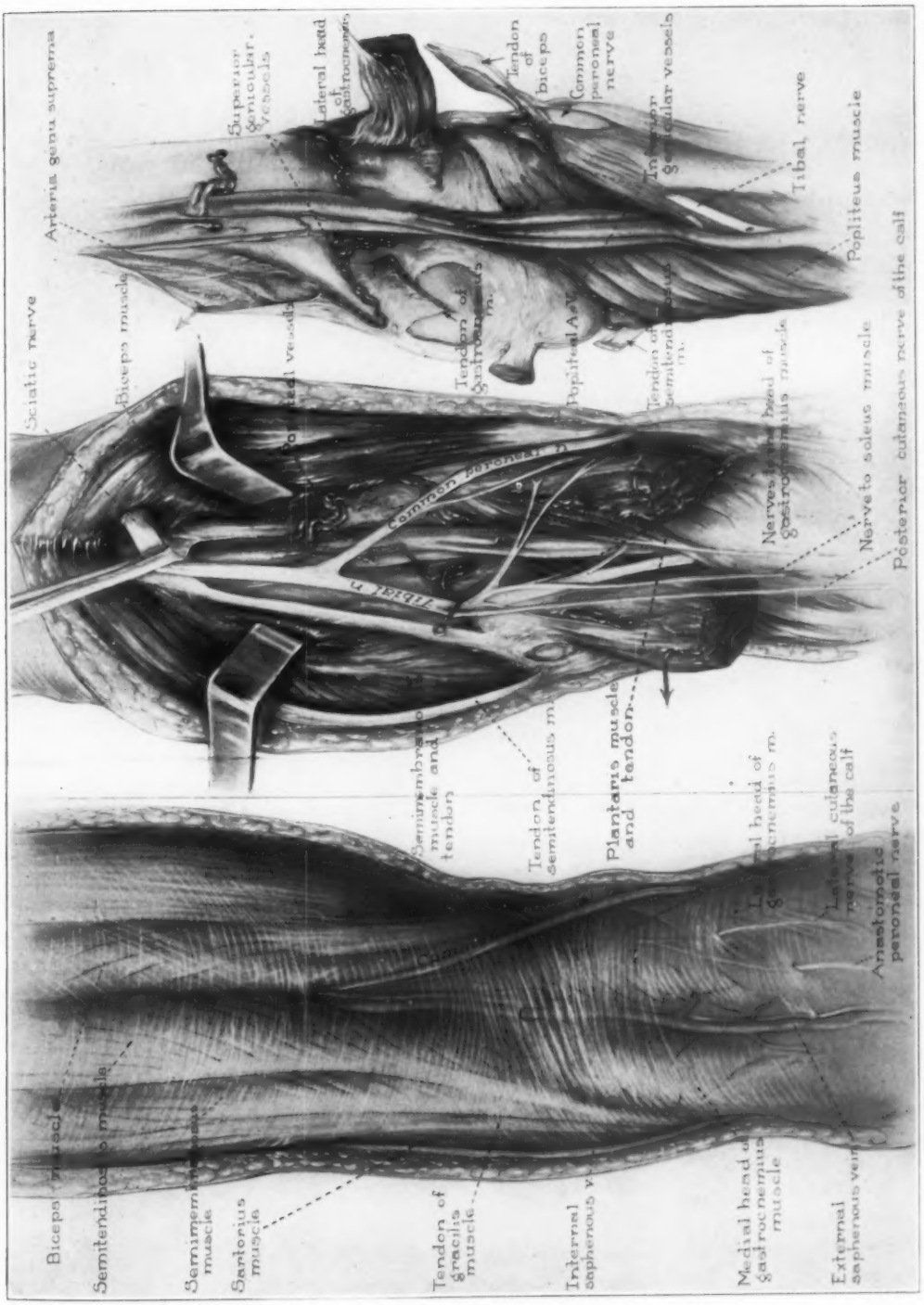

FIG. 25
An anatomical dissection of the posterior aspect of the knee.

popliteal space is entered. Incisions in front of the collateral ligaments expose the anterior part of the joint, while incisions posterior to the collateral ligaments enter the posterior compartment of the joint. In the popliteal space, there are certain fascial planes and bursae which are worthy of consideration from the viewpoint of the surgeon. The bursae between the semimembranosus and the medial head of the gastrocnemius frequently communicate with the knee joint. Consequently, incisions opening these bursae often lead directly into the joint. This is the rationale of the Klein approach on the

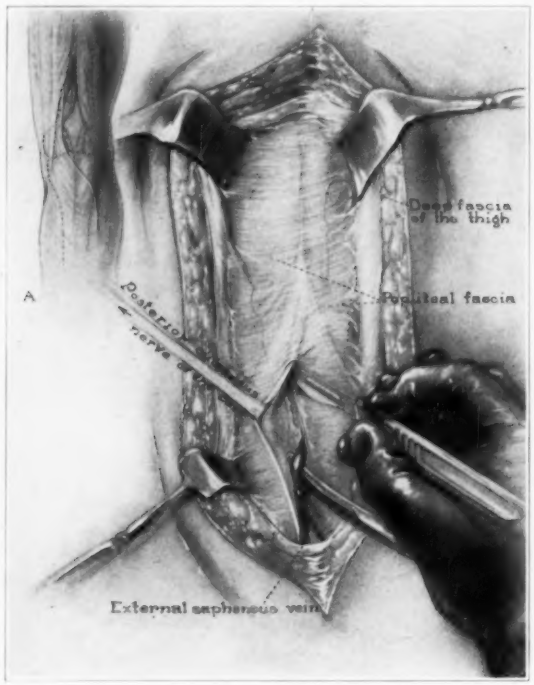

FIG. 26

The mid-line approach to the popliteal space with exposure of the posterior cutaneous nerve of the calf.

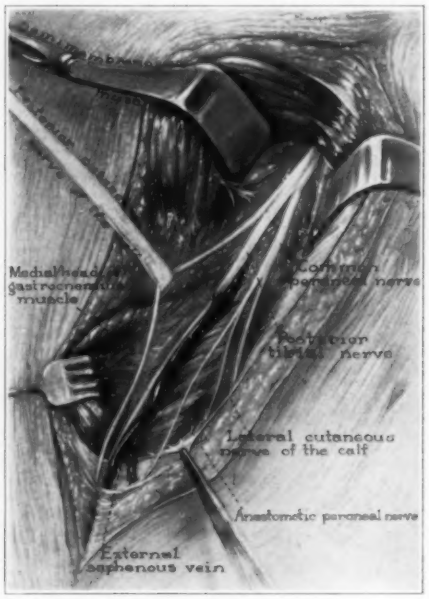
Medial head of gastrocnemius muscle
Lateral cutaneous nerve of the calf
Anastomotic peroneal nerve
External saphenous vein

FIG. 27

The mid-line incision with exposure of the sciatic nerve and its divisions.

posteromedial aspect of the joint. The popliteus tendon pierces the capsule of the joint, and a pouch of synovial membrane is prolonged on the anterior surface of the popliteus muscle. This latter is the rationale for the posteromedial incision for drainage of a popliteal abscess. The fascia of the semimembranosus and the popliteal fascia form a continuous sheath overlying the posterior compartment of the joint. Incisions from the posteromedial surface of the tibia can be followed along the anterior surface of the popliteus muscle to the postero-external aspect of the knee. Furthermore, this incision can be carried to the posteromedial condyle of the femur by dividing the insertion of the semimembranosus to the posterior part of the tibia. This permits adequate drainage of the posterior aspect of the knee, without exposing the popliteal vessels; such exposure in the presence of pus and drains may often lead to serious secondary hemorrhage, and not infrequently to amputation.

A. *Parapatellar Incisions*

1. *Indications:*
   a. Drainage of the anterior compartment of the knee joint.
2. *Position of the patient:* The patient is supine with the knee in slight flexion.
3. *Landmarks:*
   a. Patella;
   b. Joint line;
   c. Condyles of the femur;
   d. Head of the fibula.

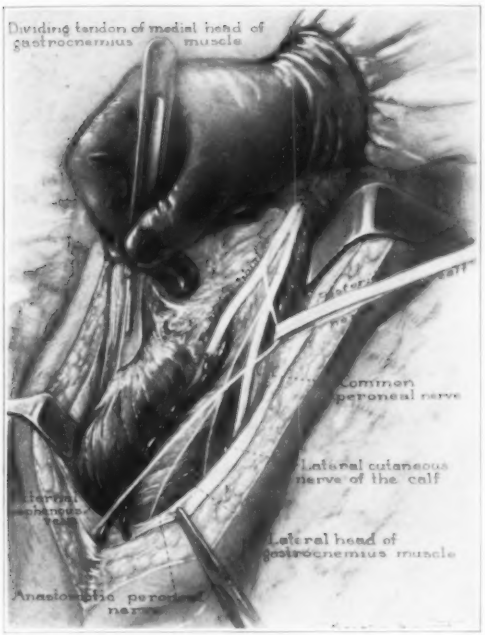
Dividing tendon of medial head of gastrocnemius muscle
Common peroneal nerve
Lateral cutaneous nerve of the calf
Lateral head of gastrocnemius muscle

FIG. 28

The mid-line posterior approach to the popliteal space with exposure of the medial head of the gastrocnemius muscle.

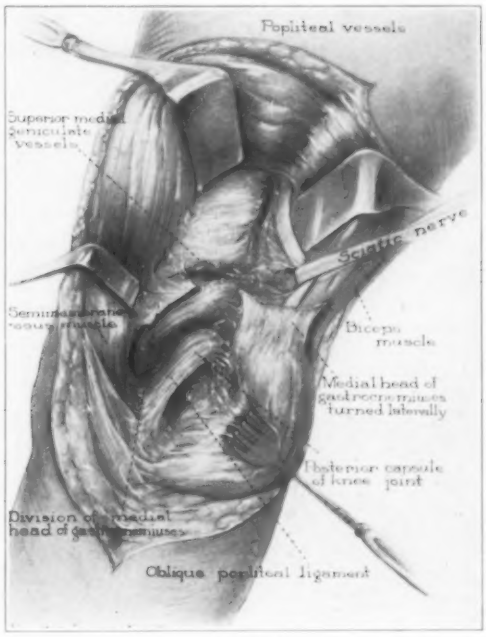

FIG. 29

The mid-line posterior incision with division of the tendinous origin of the medial head of the gastrocnemius and exposure of the capsule of the joint.

4. *Incision:* Two vertical parapatellar incisions are made on both sides of the knee. They extend from the apex of the patellar pouch above to the margin of the tibia below. Alternative vertical incisions are of the multiple short variety, or two horizontal incisions may be made extending backward from the middle of the patella to the anterior margins of the collateral ligaments. In these incisions, it is often necessary to sew synovial membrane to the skin to ensure adequate drainage, as no drains are placed within the joint.

B. *The U-Shaped Incision*

1. *Incision:* A U-shaped incision is also useful for compound fractures with severe sepsis. In the last War one of the writers (L.C.A.) used it as a life-saving measure or as a preliminary to amputation. The incision is made through the skin, patellar tendon, the deep fascia, and aponeurosis of the vasti. The U-shaped flap is turned upward, opening the joint widely. The patellar tendon is stitched to the skin on the anterior aspect of the thigh. With the knee flexed, excellent drainage is secured.

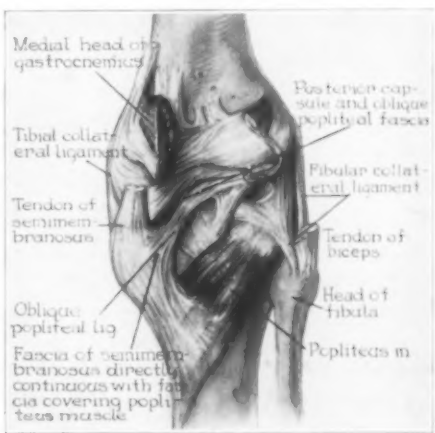
Medial head of gastrocnemius
Posterior capsule and oblique popliteal fascia
Tibial collateral ligament
Fibular collateral ligament
Tendon of semimembranosus
Tendon of biceps
Head of fibula
Oblique popliteal lig
Popliteus m
Fascia of semimembranosus directly continuous with fascia covering popliteus muscle

FIG. 30

Dissection of the popliteal space (Redrawn from Spalteholz).

C. *The Posteromedial Tibial Incision*

1. *Indications:*
   a. Drainage of popliteal abscess.
2. *Position of the patient:* The patient is supine, with the knee flexed to 30 degrees, and the hip in external rotation. The side of the foot rests on the opposite tibia. The prone position may also be used with the entire lower extremity on a sandbag well above the level of its fellow.

3. *Landmarks:*
   a. Posteromedial border of the tibia;
   b. Posteromedial border of the condyles of the femur;
   c. Internal hamstring group.

4. *Incision:* An incision, four inches in length, is made through skin and subcutaneous tissue over and well behind the posteromedial border of the upper one-fourth of the tibia to avoid exposure of the saphenous vein and nerve. These structures lie anteriorly in the subcutaneous fat, the vein usually in two divisions, one placed subcutaneously, and the other lying in the subfascial portion. The deep fascia is incised in line of the skin incision, and the soft parts are drawn forward to expose the posteromedial border of the tibia.

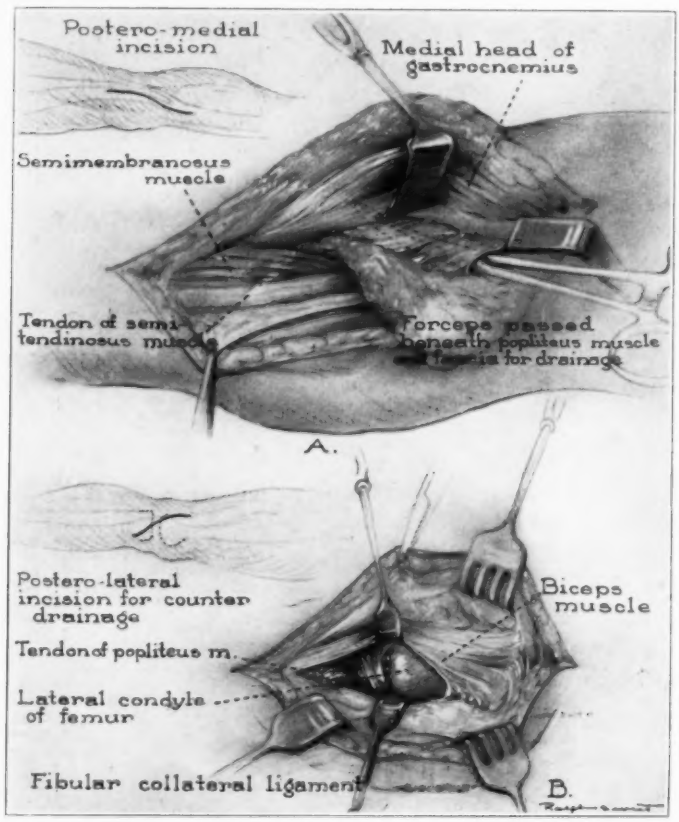

FIG. 31

A: The incision on the posteromedial aspect of the upper end of the tibia and the lower end of the femur for drainage of popliteal abscess.
B: The posterolateral incision for counter-drainage of popliteal abscess.

The posteromedial border of the tibia and the fascial covering of the medial head of the gastrocnemius are now exposed. This fascia is incised, and the gastrocnemius muscle is traced upward as far as its tendinous insertion of origin from the femur. The muscle is separated from its fascial covering to permit its retraction inward. The posterior surface of the upper end of the tibia is now displayed. Upon it lies the popliteus muscle and its insertion into the medial side of the tibia at the oblique line. From the oblique line, passing downward and medially, the fibrous origin of the soleus from the tibia is seen. The popliteus muscle is covered by fascia which is directly continuous with the fascia overlying the semimembranosus (Fig. 30). At the upper border of the popliteus, the inferomedial genicular vessels are disclosed; while lateral and posterior to the popliteus, the posterior tibial nerve and artery can be felt as they are crossed by the tendon of the plantaris. The insertion of the popliteus into the tibia is divided, and the clamp passed upward and outward along its anterior surface until it reaches the external condyle of the femur (Fig. 31, *A*). This pad of muscle and popliteal fascia forms a protection for the popliteal vessels, veins, and nerves which lie posteriorly.

During the last War, in cases of marked sepsis of the knee, it was our practice to carry the incision upward with division of the tendons of the sartorius, gracilis, and semitendinosus, and the capsule of the knee joint on its posterior medial aspect. In addition, counter-incisions were made over the posterolateral aspect of the joint to ensure better drainage. A more conservative procedure would be the posteromedial incision over the tibia, com-

bined with the operation described by Klein. This operation, with counter-incision over the postero-external aspect of the joint, gives complete drainage without undue hazard to vital structures.

D. *Arthrotomy of the Knee by a Posteromedial Femoral Incision (Klein)*

1. *Indications:*
   a. Drainage of the posteromedial aspect of the knee in sepsis.
2. *Position of the patient:* The patient is placed in the prone position, with the leg supported on a sandbag which raises it well above the level of the opposite leg.
3. *Landmarks:*
   a. Medial hamstring muscles;
   b. Medial condyle of the femur;
   c. Joint line;
   d. Upper medial margin of the tibia.
4. *Incision:* The incision is four inches in length, and is made over the posteromedial aspect of the knee, just lateral to the semitendinosus, its center being over the line of the knee joint. The subcutaneous fascia is incised, and the tendons which are exposed are the sartorius, the gracilis, and the semitendinosus, lying over the posterior and the posteromedial aspects of the internal condyle of the femur. Directly posterior to the sartorius is the saphenous branch of the arteria genus suprema. On the surface, but deep to the fascia lata, is the internal saphenous vein. The intervals between the gastrocnemius and the semimembranosus are identified, and the gastrocnemius is then followed up to its insertion into the medial condyle of the femur. In this latter interval between the gastrocnemius and the semimembranosus, the capsule is exposed and incised.

E. *Incisions for Counter-Drainage on the Posterolateral Aspect of the Knee.*

1. *Incision:* Curved or straight incisions for drainage on the posterolateral surface of the knee are made between the iliotibial tract and the biceps tendon. The capsule is incised behind the fibular collateral ligament, with exposure of the tendon of the popliteus muscle where it inserts into the lateral epicondyle of the femur. If used with the posteromedial approach, through-and-through drainage is obtained (Fig. 31, *B*).

SUMMARY

In this article the writers describe the anatomical details of the surgical approaches which they have found to be the most successful in operations upon the knee joint. This judgment is based upon their clinical experience and that of their colleagues (including a study of motion pictures taken while operations upon this joint were being performed), upon a comprehensive review of the available literature on the subject, and upon a survey of a number of dissections performed on cadavera and freshly amputated specimens.

The writers wish to express their appreciation to Dr. John B. deC. M. Saunders, Professor of Anatomy, who has been generous with his time and his exact knowledge of both human and comparative anatomy.

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ADJUSTABLE CASTS IN THE TREATMENT OF JOINT DEFORMITIES*†

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The value of supporting plaster casts for the prevention and correction of deformities in joint disease, particularly in rheumatoid arthritis, is well recognized. Support of an involved joint, which is kept flexed by muscle spasm, permits the spasm to subside, and allows the flexion deformity to diminish. The simple bivalved variety of cast has been used successfully for many years on the Arthritis Service at the Massachusetts General Hospital. Bivalved casts have been used so that they could be removed several times a day, in order that the joints might receive hot packs and exercises in bed, important features of the treatment. As soon as a flexion deformity had decreased by 10 degrees or so, a new cast of the same type was made, thus permitting further relaxation of the joint.

For the past two and a half years these bivalved casts have been made adjustable by the application of hinges. Adjustable casts, particularly for knees and elbows, have been found to possess several advantages. Much time, material, and labor are saved by avoiding the necessity of frequent renewal of an entire cast when the deformity is improving, or when, as occasionally occurs during an exacerbation of the disease, it is temporarily increasing. Compensation for variations in the amount of flexion deformity can be more

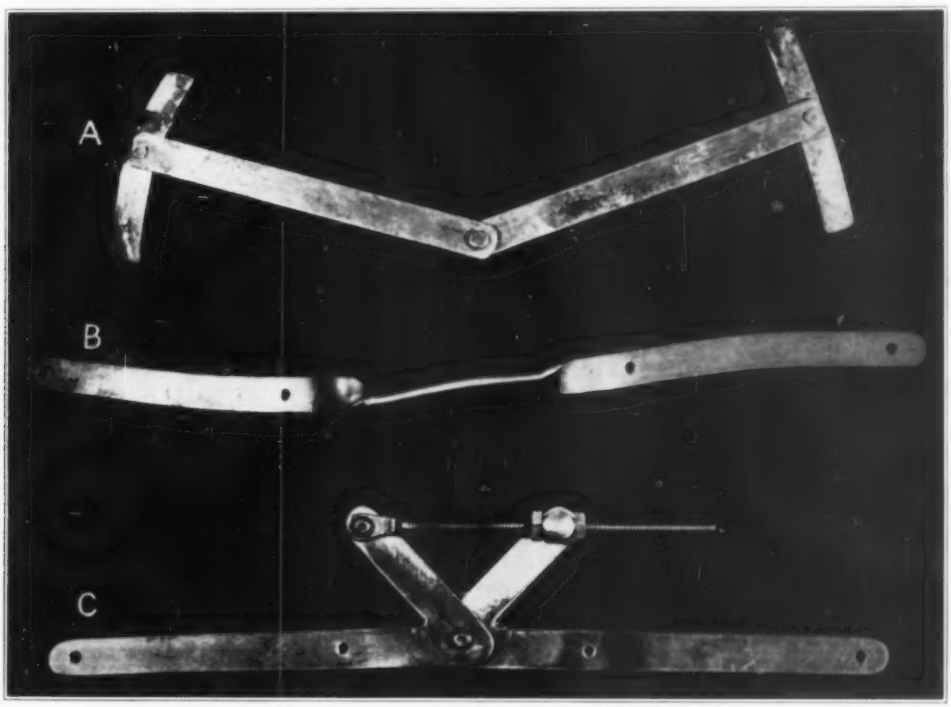

FIG. 1

Types of hinges used in pairs for knees (*A*, *B*, and *C*) and elbows (*A* and *B*).

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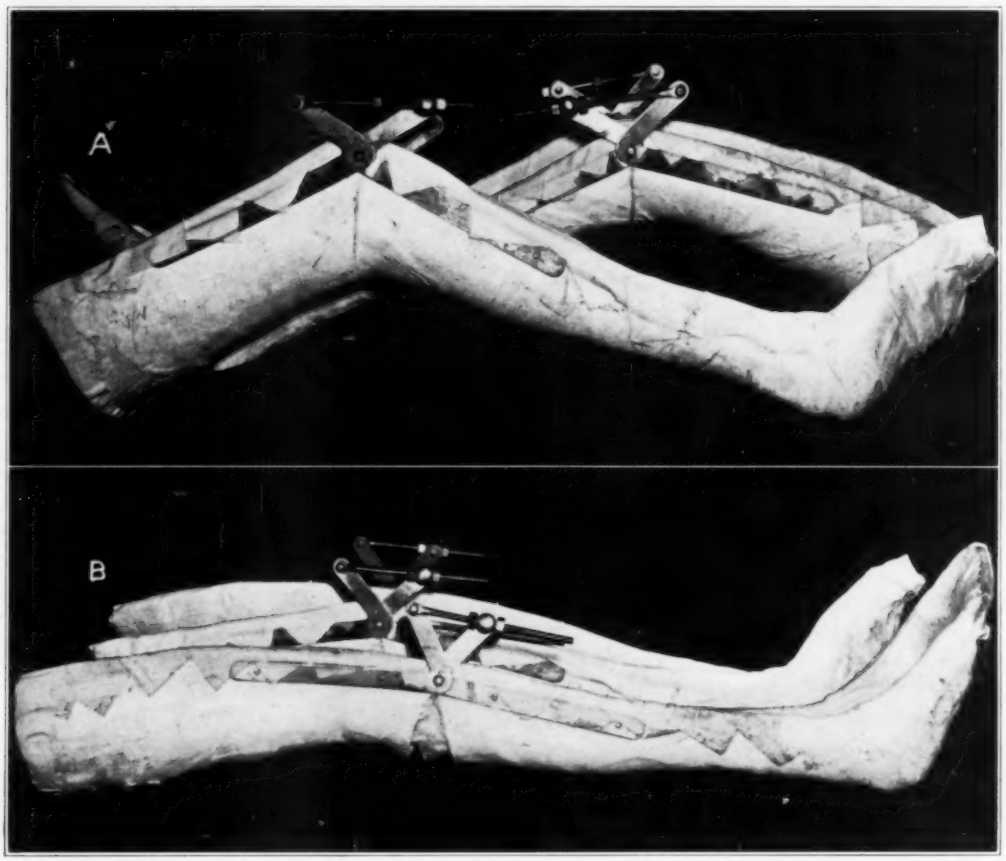

FIG. 2

Posterior shells of two leg casts with screw-type hinges (See Fig. 1, *C*).
A: Position of flexion deformity in which casts had been applied.
B: Corrected position obtained.

accurately achieved by a mechanical adjustment, which can be altered daily if necessary. A cast which accommodates itself to the deformity closely at all times is most effective in accomplishing relaxation of the muscles which are in spasm about an inflamed joint.

The photographs demonstrate the varieties of adjustable casts employed on knees. The two bivalved types shown in Figures 2 and 3 are used most frequently. The non-removable type illustrated in Figure 4 is occasionally employed on selected patients. The metal hinges * (Fig. 1) used on all casts have been easily made in the Orthopaedic Workshop of the Hospital. One pair of hinges is used repeatedly on successive patients.

The casts shown in Figure 2 are employed on joints with severe flexion deformities of an acute or subacute nature. The casts are applied cylindrically over two thicknesses of sheet-wadding from toe to groin, with the ankle and knee in as fully corrected position as is possible without strain. As soon as the plaster has set, the cast is bivalved, making the posterior shell about twice as deep as the anterior shell. The cast is removed and the sheet-wadding discarded. The plaster shells are placed in a warm cabinet for drying. A pair of metal hinges (Fig. 1, *C*) is riveted to the posterior shell, at the level of the femoral condyles. After the hinges have been attached, the plaster is sawed across to permit

* The hinge, shown in Figure 1, *C*, is a modification of Turner irons as regards construction, but it has the important functional difference that the undesirable element of constant pressure, generally exerted by Turner irons, is eliminated.

This is, as far as we know, the first time that hinges of the type shown in Figure 1, *A* and *B* have been used on adjustable casts.

motion as the hinge is adjusted. The anterior shell is only partly sawed through, from each side. The middle segment of plaster overlying the patella is fractured to act as a hinge. Adhesive plaster and leather, riveted in place, are used as reinforcement, permitting sufficient flexibility to accommodate this shell to the altered positions of the posterior, supporting shell. Finally, after irregularities on the inner surface of the plaster have been smoothed off, the cast is padded. Two thicknesses of sheet-wadding or a thin layer of soft felt are covered by one thickness of stockinette, fastened to the edges of the plaster by adhesive tape. The stockinette follows closely the contours of the cast. It is important that the stockinette should nowhere act as a sling. This is especially difficult to prevent at the heel, where the avoidance of pressure is most important. The stockinette should be laid loosely but evenly along the bottom of the depression for the heel. This produces a fold of stockinette on either side. These folds should be cut out, and the cut edges of stockinette overlapped by a strip of adhesive down each side of the heel.

The hinges (Fig. 1, *C*) are attached to the posterior shell of the cast by rivets. Adjustment of the hinges by the lock nuts on the screws is readily carried out with a pair of pliers. The nuts must be kept tight enough to prevent the patient from turning them himself. In making an adjustment, care is taken that the cast is not extended far enough to put strain on the affected joint, rather than to support it at rest, as is necessary to relieve muscle spasm. In other words, when a cast is adjusted, extension is increased only to the amount of taking up the slack between the present position of maximum extension obtainable without strain and the position at the last adjustment of the hinges.

This type of hinge (Fig. 1, *C*) is used on hospital patients who have severe flexion deformities. When a patient has only a mild flexion deformity, or is going to wear the cast at home, the type of "hinge" shown in Figure 1, *B* is employed. Plaster shells are made as already described. A metal strip, the central portion of which has been twisted through an angle of 90 degrees, is riveted to either side of the posterior shell at the knee (Fig. 3). By the use of "bending irons" (or two monkey wrenches) on the central portion of each strip, the flexion at the knee can readily be increased or decreased. It is essential that the metal strip be fairly stiff. The middle, flat portion need be only long enough to accept readily the bending irons. The leather hinge, used on the anterior shell of this type of cast, is the same as that described previously.

Bivalved casts with one of the above types of hinge are worn at night and for part of the morning and afternoon. It is essential that they be removed for regular periods every day. During such intervals hot packs are applied to the joints, and the patients are permitted to move their joints freely in bed, or are given supervised exercises without

FIG. 3

Anterior and posterior shells of leg cast with bendable strip "hinges" (See Fig. 1, *B*). Position of final correction.

weight-bearing. When the patients are awake and in the supine position, and are cooperative, it is not necessary for the tops of the casts to be used. At night the tops are held in place by webbing straps.

These bivalved casts are employed on joints where it can be expected that relaxation of muscle spasm by simple support of the limb for periods during the day and night will bring about correction of a recently acquired flexion deformity. On carefully selected patients in whom the flexion deformity is of long duration and has not responded to a bivalved cast, an adjustable cast (Fig. 4), which embodies a more constant corrective factor, can be used, if synovial inflammation is absent or relatively quiescent. This cast is non-removable, and, while extension is being gained, there may be an associated loss of flexion. Such a cast is used, therefore, only when straightening a leg is of paramount importance,—as for instance when walking is the primary concern.

A well-padded plaster cylinder is applied from toe to groin, with the knee in maximum free extension; and it is not bivalved. After the plaster has hardened thoroughly, a pair of simple metal hinges (Fig. 1, *A*) is attached opposite the femoral condyles with plaster bandages (Fig. 4). The axis of rotation on each hinge should be situated slightly anterior to the axis of the femoral condyles about which the tibia rotates. This produces a tendency for the joint surfaces to be distracted, as the cast is extended. It is important, however, that the cast axis of rotation should not be too far anterior, for that would induce too great a shift of the cast on the leg, as it was flexed and extended.

The cast is sawed circularly at the level of the hinges. The sawing at the two sides should be carried out before the hinges are placed. After the hinges are firmly attached, sawing the front and back can be readily completed. The plaster over the patella should be removed, as well as that over the dorsum of the foot (Fig. 4, *C*). The latter permits exercise of the ankle. A segment of plaster may also be removed from behind the knee to allow additional flexion during the exercise periods. Since such a cast does shift somewhat on the leg as extension is gained, it is very important to watch closely for excess pressure on the skin at any point, and to question the patient on this score. Development of undue pressure can be avoided by anticipation. The cast in the photograph has been cut out over the lateral malleolus to prevent such pressure.

During most of the twenty-four hours, maximum extension of the knee is maintained by placing a block of wood in the gap in the cast behind the knee (Fig. 4, *B*, white arrow). A notch in each end of the block keeps the latter from falling out. Hardening the cut edges of the cast with several coats of collodion makes the block easier to insert and remove without fraying the plaster. Again, it is essential that no force be used in inserting the block. Forcible extension produces pain and protective muscle spasm, thus retarding the correction process. A longer block of wood to fill the widening gap is adopted only when sufficient slack for further free extension has developed, usually after five to seven days.

It is extremely important that motion at the affected joint be performed daily. The block is removed for brief periods several times a day for active exercise. The photograph (Fig. 4, *A*) shows the ankle in a sling, which is rigged to a handle by a pulley on a Balkan frame, to aid the patient in exercising the joint by himself. It is much safer to use a block of wood than an adjustable mechanical device to maintain extension in these casts, because in this way it becomes impossible for anybody inadvertently to apply more extension than the length of the block produces. Such a cast must not rest on the heel, as that would lead to strain at the knee joint. The cast should be supported by a pillow beneath the calf of the leg.

It must be emphasized that this type of non-removable cast is used only where it is thought to be more important to gain maximum extension of the leg than to preserve maximum motion at the joint. Even so, while extension is being accomplished, all possible motion is preserved by the frequent removal of the block for exercise of the joint.

For elbows, adjustable casts are used with similar precautions. All casts are applied

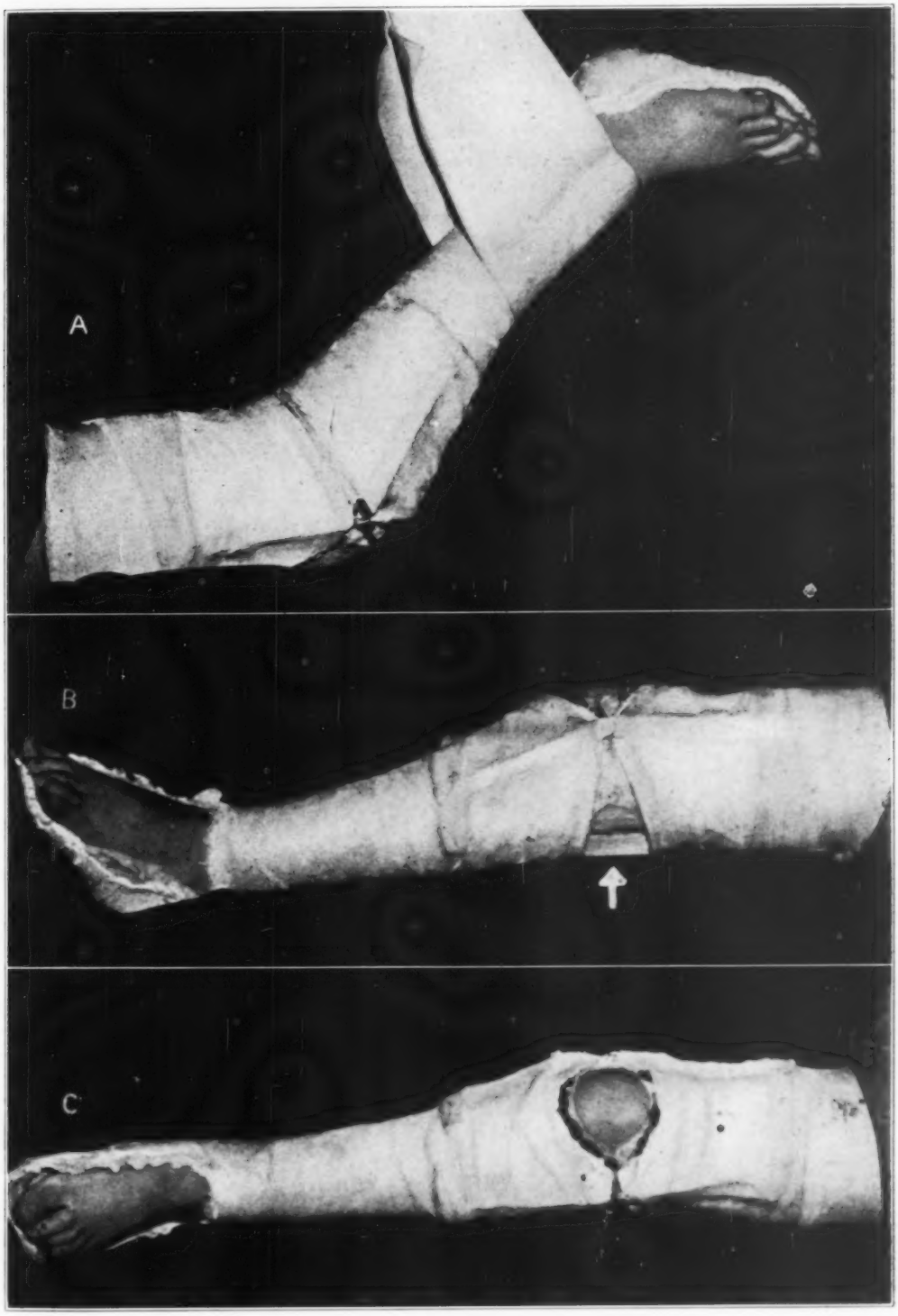

FIG. 4

Non-removable cast with simple hinges (See Fig. 1, *A*).
A: Position of original flexion deformity in which cast had been applied.
B: Extension which had been gained. Arrow points to removable wooden block behind knee.
C: Anterior view.

in maximum free extension. It is important to place the axis of rotation of hinges opposite the humeral condyles, and not opposite the olecranon. When bivalved casts are employed, the metal strip "hinges" which are adjustable by bending irons are used (Fig. 1, *B*). The more elaborate screw type of hinge (Fig. 1, *C*) would be too bulky for the elbow. The metal strips are riveted to the deeper posterior shell, and a segment of plaster is cut out over the olecranon to permit extension. The anterior shell is partially cut, fractured, and reinforced with leather, as on knee casts. Non-removable casts with simple hinges (Fig. 1, *A*) and a wooden block are employed for the same indications as in the knee. The details of the application and the cutting of the casts are also essentially similar.

Bivalved and solid casts, with adjustable screw hinges or with bendable metal strips, have been employed in the correction of equinus and varus deformities at the ankle. Volar wrist splints, which are held in place by webbing straps, have been fitted with bendable metal strips to accommodate them to gains in extension. By far the most frequent and valuable use of adjustable casts, however, has been for knees and elbows.

SUMMARY

Types of adjustable plaster casts which have been used advantageously for the treatment of flexion deformities of knees and elbows in patients with rheumatoid arthritis and other joint diseases have been described. Such casts remain effective for many weeks, and represent a great saving of time and labor as compared with the practice of making an entirely new cast every week or two, as the deformity of a joint improves. Furthermore, in comparison with other varieties of casts and traction, it has become apparent that these hinged casts, kept well adjusted to the joints and without strain at all times, provide the most effective correction of deformities. The importance of daily exercise of the joints without weight-bearing cannot be too strongly stressed. Although adjustable casts exhibit their chief value for knees and elbows, they are useful occasionally at other sites.

RESEARCH WORK ON A MORE PRECISE METHOD OF DETERMINING MUSCLE STRENGTH IN POLIOMYELITIS PATIENTS

A New Muscle Tester *†

BY ADOLPH A. SCHMIER, M.D., NEW YORK, N.Y.

The purpose of this study has been to devise a more accurate method of determining the strength of muscle groups in poliomyelitic patients. The work was instituted at the Hospital for Joint Diseases and has been carried out on the Services of Dr. Leo Mayer, Dr. Harry Sonnenschein, Dr. Henry Milch, and Dr. Jerome Weiss.

The assumption that a single muscle can contract without stimulating agonistic as well as antagonistic muscles is not generally true. We are unable to evaluate the actual strength of individual muscles unless all neighboring muscles have lost their function, either by loss of innervation or by their section. Even the strength of a group of agonistic muscles cannot be definitely determined, unless we allow for the action of antagonistic muscle groups. Actually, we test the resultant action of a group of muscles to move a segment of the body about its axis of motion, or joint; and the strength with which it can do so. The strength with which a segment of the body moves also depends upon the synergistic response of distant muscles, which by their action do not even move the segment being tested. These latter muscles fix or stabilize the neighboring movable part of the body, in order to allow the muscles being tested to have a firm origin from which to pull. For instance, during knee extension against resistance, with the patient either in the sitting or side-lying position, the hip extensors tend to fix the thigh in complete extension. Without such thigh stabilization, the knee cannot be extended with maximum strength. If two patients with exactly equal knee-extension power but unequal hip-extension power were examined, it would be found that the recorded knee-extensor strength would be stronger in the case with stronger hip extensors. In other words, a patient cannot use a muscle group to the greatest advantage unless distant muscle groups, which have no primary action in moving the tested segment around its joint, function synergistically so as to enhance the power of the muscle group being tested by stabilizing the adjacent body segment. This principle is taken advantage of when testing patients with the scale method, by stabilizing the adjacent segments mechanically.

For practical purposes, we can enumerate the various muscles which move a given segment of the body in a certain direction. We can then assume that the strength with which the segment moves in this direction is the actual strength of the muscles enumerated. In order to evaluate the proportional strength of each of these muscles separately, two methods are open to us. The first is the method of palpation. The examiner palpates the muscle in order to estimate its contractility and approximate strength. The result varies with the subjective knowledge and ability of the examiner and is, therefore, unreliable. The second method of determining the proportional strength of a single agonistic muscle is by employing the isolation test. It is carried out in such a way that the tested segment of the body is moved primarily by a single muscle. The other agonistic muscles are placed at a mechanical disadvantage by being completely relaxed; thus their effective action is minimized. For instance, the combined action of the gastrocnemius and soleus plantar-flex the foot. By completely flexing the knee, the gastrocnemius is relatively

* Presented to The New York Chapter of The American Physiotherapy Association, January 15, 1941, and to The New York Physical Therapy Society, February 5, 1941. A talking motion picture in color, illustrating the apparatus and technique of examining patients was exhibited at the ninety-second annual session of The American Medical Association in Cleveland, Ohio, in June 1941, and to The American Physiotherapy Association at Stanford University, Palo Alto, California, in July 1941.

† This research was aided by a grant from The National Foundation for Infantile Paralysis, Inc.

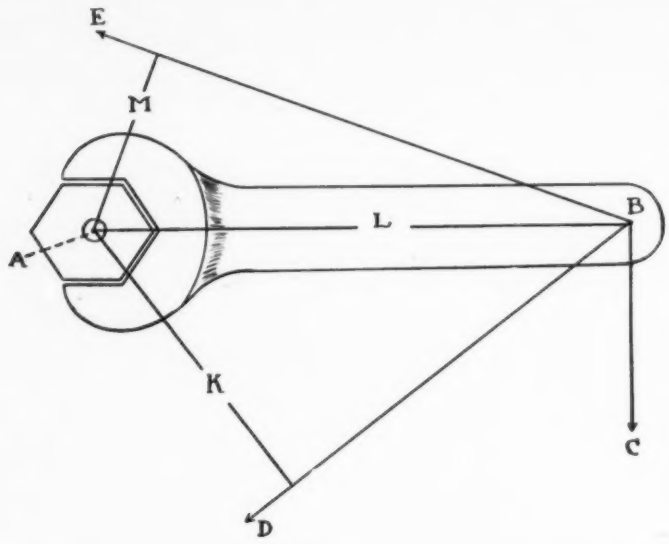

FIG. 1

Moment of force. An equal force acting through the spanner on the bolt *A* in the directions *BA, BE, BD, BC* will produce the greatest moment of force when acting along the direction *BC*. The moment of force depends upon:

1. The magnitude of the force acting.
2. The distance of the force from the axis of the body upon which it acts, measured along a line at right angles to the line of action of the force.

lengthened and relaxed, thereby diminishing its tension and its contracting efficiency. It is now unable to contract sufficiently to plantar-flex the foot with any appreciable power. The soleus, therefore, becomes primarily responsible for plantar-flexion of the foot.

It has long been known that the determination of muscle strength by the manual method is only approximate, and attempts have been made, first by Lovett and Martin, to increase the accuracy of these tests. Some years ago, the writer began to employ a rectangular spring scale with ink pointer attachment in order to record the results in pounds and ounces. The original method has been reported in a previous publication.[4]

In order to record the maximum strength of a muscle group, the following principles must be adhered to. The scale must be strong enough to prevent the tested segment from completing its arc of motion. Each of the rectangular spring scales was so constructed that its indicator was required to go through an excursion of five inches for maximum recording. Since many body segments do not move normally through a 5-inch range, it was impossible to determine their maximum strength with these scales. It was, therefore, necessary to replace the rectangular scales with a single circular scale of sufficient strength to test the strongest muscle group in the body. Circular scales require a minimal arc of motion of their indicator, in order to record maximum strength. This applies equally to the circular-spring and gravity-lever type of scale. It was ascertained that either would be satisfactory, provided it is circular. A 180-pound scale of the gravity-lever type was obtained, permitting readings as low as four ounces. This scale requires a minimal arc of motion to record maximum strength. A maximum lever pointer was attached to the scale, thereby allowing the examiner to perform the test without the necessity of watching the scale. It was attached to the glass cover of the circular scale by means of a ball-bearing rotating joint. Its movement coincides with the movement of the regular indicator, and when the tested muscle relaxes, the maximum lever pointer retains the position of maximum muscle pull. It therefore allows the maximum muscle strength to be read after the test is completed. This scale is similar to that used by Mayer and Greenberg.[3] It differs in that it has a special housing, a special base, and a maximum lever pointer; it can be attached to the table in any desired position.

The table employed has been designed in order to test all important muscle groups of the trunk as well as the extremities with the least possible source of error and the least discomfort to the patient. It has a flat top surface with narrow trunk end and wide extremity end. Triangular sections of the top can be removed, allowing the trunk portion to swivel from side to side by means of a ball-bearing joint, when an appropriate lock is released. By stabilizing the pelvis, the strength of the muscle groups that move the trunk

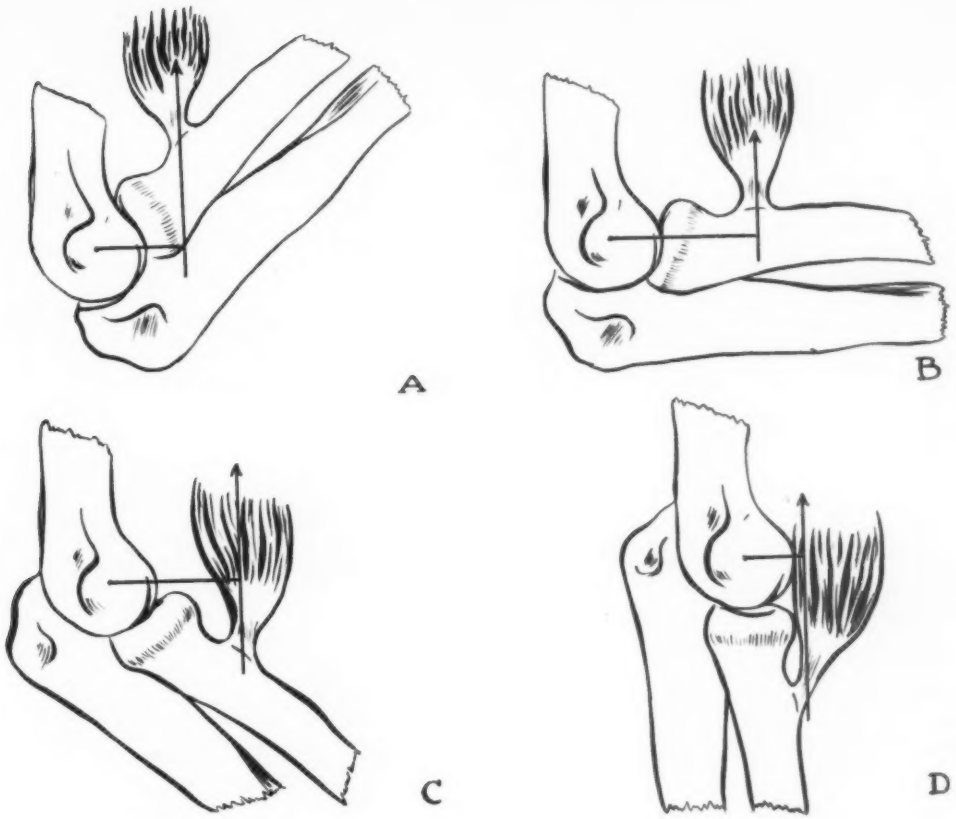

FIG. 2

Optimum angle for obtaining maximum moment of flexion force at elbow. From mathematical standpoint, the moment of flexion should be greatest with the tested movable segment at right angles to the neighboring fixed segment. In the human body, however, we must consider the position which gives the maximum muscle tension or muscle tone. In the elbow it is 180 degrees for the flexors. A combination of both factors determines the proper angle to measure muscle strength. The optimum angle for elbow flexion is 115 degrees.

can be determined. By locking the movable portion of the table, and replacing the triangular sections, an intact, flat top, table surface is obtained for testing the extremities. Two metal rails encircle the table. The upper rail permits the various appliances to be attached to it in any desired position for stabilizing the patient on the table. The scale is mounted on a triangular base with ball-bearing rollers and moves along the lower encircling rail. It can be fixed to the rail in any desired position. The tested body segment is attached to the scale by means of a web strap, in order to record the strength of its tested muscles. The scale and its housing are mounted on the base by means of a ball-bearing swivel joint, permitting the scale to swivel on its long axis. By this means, the scale follows the movement of the tested body segment, allowing a right-angle pull on the scale at all times. The various appliances stabilize adjacent body segments, permitting movement of only that segment whose activating muscles are being examined.

The conditions under which the tests are made should be uniform. This is important when interval examinations are repeated on the same patient in order to determine progress. The examined segment should be uniformly warm. A cold extremity cannot function as well as a warm one. The technique for testing each group of muscles has been carefully devised and standardized. It is important to note that wherever possible the tests are performed with gravity eliminated. This is possible in all instances except where rotatory movements are being performed. Particular attention is paid to proper stabilization in order to avoid substitution action. Before a given test is carried out, the tested

segment should be passively moved through its complete arc of motion. This will reveal any existing contractures, which by their presence hinder free action of the muscles being tested. In the presence of fixed contractures, free joint movement cannot be obtained, and the readings must, therefore, be accepted with reservation.

When examining the strength of muscle groups, one must have some knowledge of the mechanical events occurring during muscle action. (The amount of work performed by a contracting muscle is the product of the force used by the distance or extent of movement. $W = F \times D$. One unit of work is the amount involved in exerting one unit of force through one unit of space. Work is ordinarily measured in gram-centimeters or foot-pounds.) In this study we are primarily interested in measuring the force expended by the tested muscle group in attempting to move the segment against resistance. A force is characterized by its magnitude, its point of application, its direction, and its sense,—that is, whether the force is push or pull at the point of application. In the human body, a muscle always exerts a pulling force at its point of application, or insertion. Forces may produce or tend to produce motion of translation,—that is, motion in a straight line. A force may be applied to a body to produce or tend to produce motion of rotation. In the human body, muscle action tends to produce motion of rotation of a segment about its joint or axis. The turning effect of a force which tends to produce rotation is called the moment of force. Its measure depends upon:

1. The magnitude of the activating force.
2. The distance of the force from the axis of the body upon which it acts, measured along a line at right angles to the line of action of the force.

These two factors together determine the turning effect, and their product is called the moment of force. From a mathematical standpoint, the moment of force, or muscle strength, will be greatest when the tested movable segment is at right angles to its neighboring fixed segment. In measuring muscle strength, however, one must consider not only the ideal mechanical principle, but also the position in which the tested muscle possesses its maximum tension or muscle tone. In the human body, therefore, these two factors determine the moment of force. For example, one would expect the moment of force of the elbow flexors to be greatest with the elbow at 90 degrees, and with a web strap from the scale attached to the forearm at the level of insertion of the biceps and brachialis anticus. At 90 degrees, however, the tension of the elbow flexors is less than when the elbow is at 180 degrees. An optimum relationship between the mechanical principle and muscle tone had to be determined for each joint movement, in order to obtain the greatest moment of force. Testing his own right elbow flexors, the author obtained the following results when the angle of the elbow was in the following positions:

Elbow at angle of 175 degrees, force equals 21 pounds.
Elbow at angle of 155 degrees, force equals 36 pounds.
Elbow at angle of 135 degrees, force equals 42 pounds.
Elbow at angle of 115 degrees, force equals 44 pounds.
Elbow at angle of 90 degrees, force equals 36 pounds.

The technique devised for testing all muscle groups in the body has been based upon the principles already outlined.

A total of 367 patients have been examined with this apparatus. Of these, 237 were "normal", and 130 were poliomyelitic patients. Twenty of these cases, including five "normals" and fifteen poliomyelitic patients, were examined with the spring scale, before the original table was made. Of the total number examined, 234 cases, including 173 "normals" and sixty-one poliomyelitic patients, were examined with the spring scale and muscle-testing table. The remaining 113 cases have been examined with the latest apparatus, consisting of a gravity-lever type of scale and swivel table. Only one person

is necessary to adjust the patient and the apparatus. After the patient is in position, the examiner no longer plays an active part in the test. Any source of error relating to the examiner is, therefore, eliminated. The same test can be performed by more than one examiner with the same result, providing identical technique is employed.

This method of testing muscle strength in poliomyelitic patients is not being advocated to supplant completely the manual method of testing muscles. Patients whose

FIG. 3

New table and scale employed. Triangular sections of the table top can be removed, permitting narrow trunk end of table to swivel on a ball-bearing joint to test trunk-muscle strength.

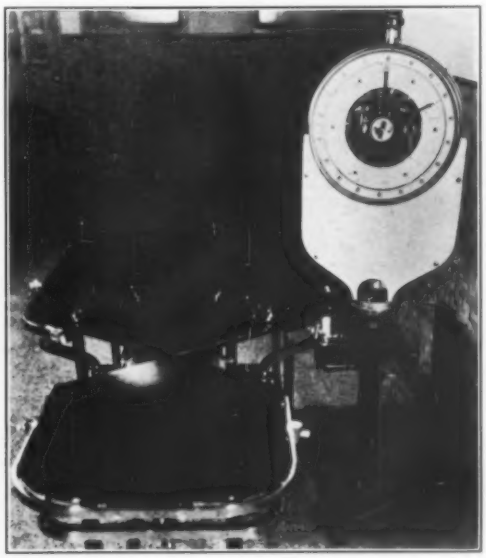

FIG. 4

Table with triangular sections removed, revealing the circular ball-bearing joint which permits the trunk end to swivel when lock on head end is released.

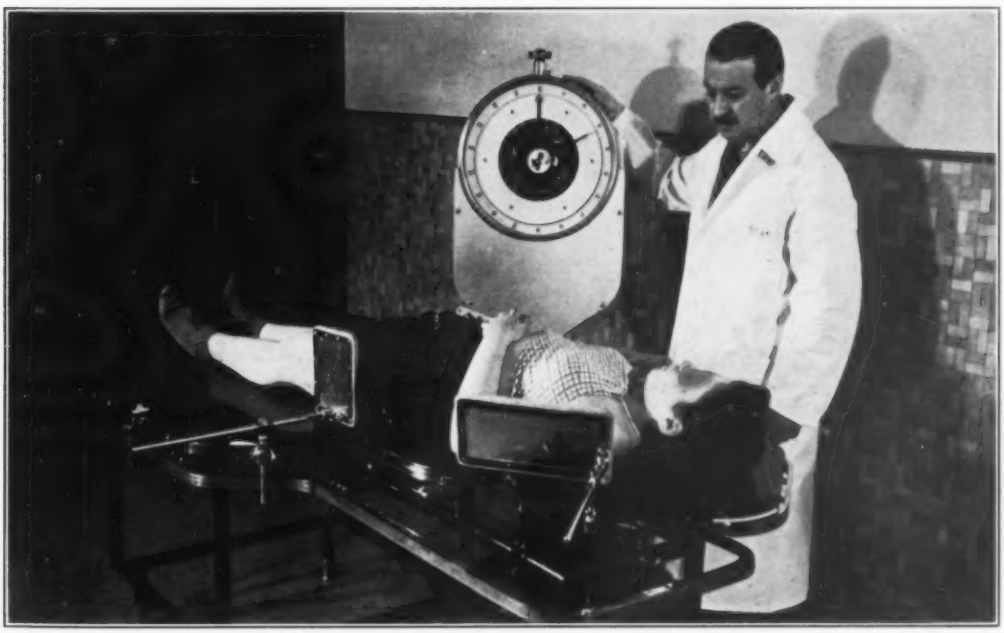

FIG. 5

Testing left lateral flexion of trunk (lateral abdominals). Note pelvis stabilized to fixed broad end of table; trunk is fixed to narrow movable portion of table.

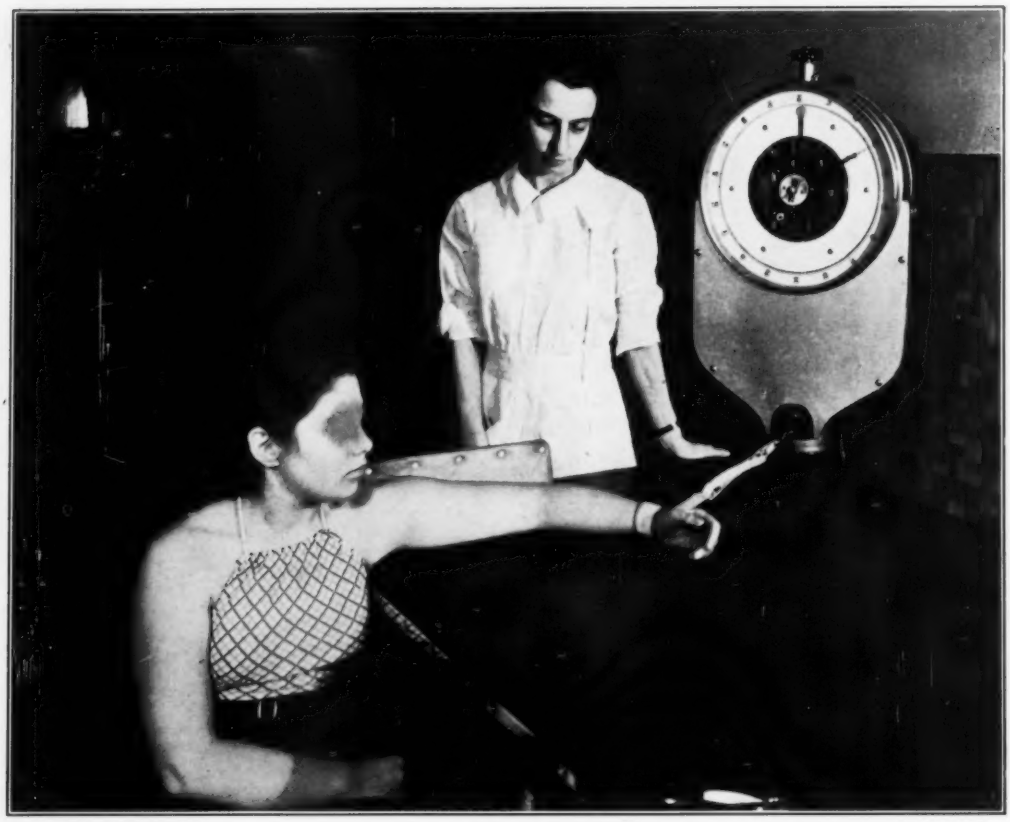

FIG. 6

Testing elbow flexors; elbow at 115 degrees. Note stabilizer which fixes shoulder and upper arm. Gravity is eliminated. Table is powdered.

muscles have been so weakened that they rate only a *1* cannot be tested by the scale method. It is obvious that some active movement of the tested segment is essential in order to be recorded upon the scale. A tested muscle group must, therefore, have a manual strength of at least *2* in order to be recorded. In the latter cases, however, it is felt that the determination of muscle strength can be more accurately obtained by the scale method than by the manual method. An attempt has been made to correlate the findings in poliomyelitic patients with the average findings in normal individuals. The series of normal individuals examined were grouped according to age, height, weight, and sex, and the average strength of the various muscle groups was determined. The number of cases in each age group varied from three to seventeen, with a total of 237 normal cases examined. It is evident that the number in each group is too small to permit definite conclusions. However, a number of observations were made, and these can be checked by additional examinations. The strength of corresponding muscle groups varied considerably in patients in the same age class. Generally, the older the patient, the stronger were the corresponding muscle groups. This is not absolute, however, since many younger patients were found to be stronger than the older patients. The sex of the patient in the same age group gave no definite indication of the muscle strength. Quite often the female group was stronger than the male group. Similarly, the height of the patient bore no relation to muscle strength. It was not uncommon to find the shorter individual to be the stronger. The weight of the individual did not relate to muscle strength. It is evident, therefore, that the average strength of muscle groups may be quite different from the actual strength in normal individuals in the same classifications. An attempt was then

FIG. 7

Testing supination of forearm. Note special brace which immobilizes wrist and articulates with rotating joint by means of metal rod. Elbow is at right angles; forearm begins in pronation of 90 degrees. Similar technique is employed with new table and scale.

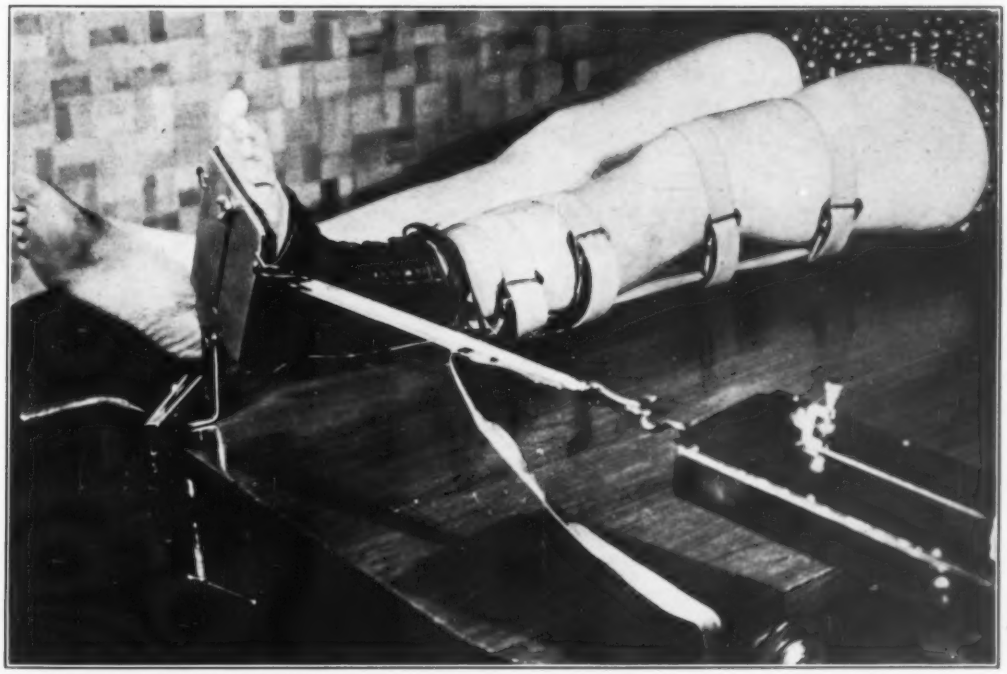

FIG. 8

Testing internal rotation of left hip. Tested leg is immobilized in special brace which maintains foot at 90 degrees and knee at 180 degrees. Foot piece, as well as leg trough, is extensible to fit extremities of various sizes. In addition, adults' and children's sizes are employed. Knob on heel of foot piece articulates with rotating joint, which on new table is attached to rail. Tested leg begins in external rotation of 45 degrees.

made to determine whether muscle strength was related to the length of the extremity or to its segments; to segment area; or to segment volume. The length of the lower extremi-

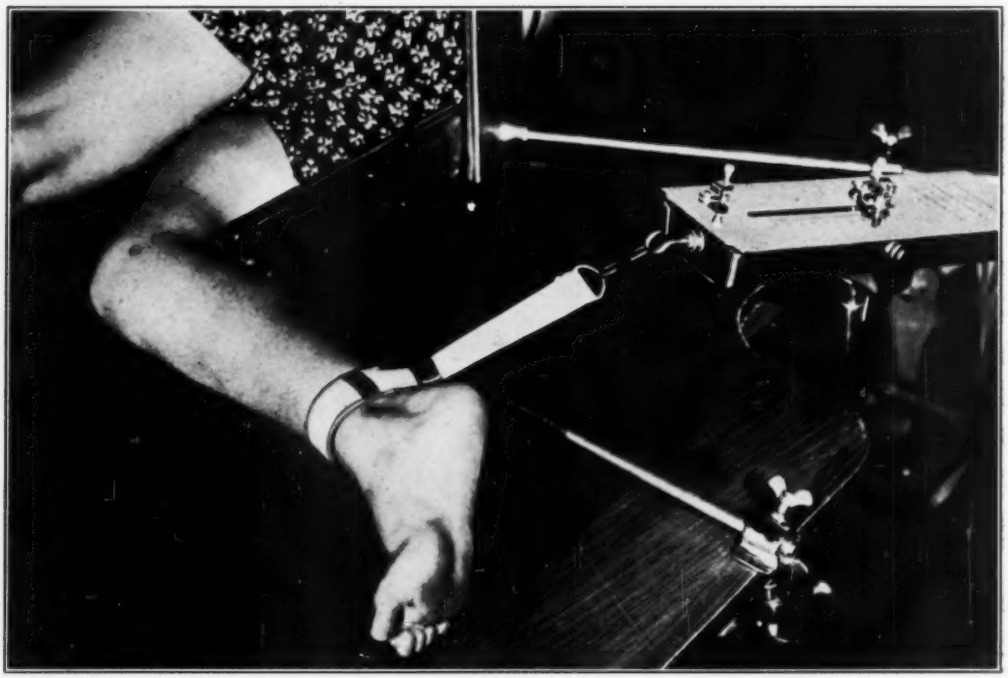

FIG. 9

Testing extension of knee (quadriceps). Pelvis and thigh are stabilized at 180 degrees. Measurement of power begins with knee at 90 degrees.

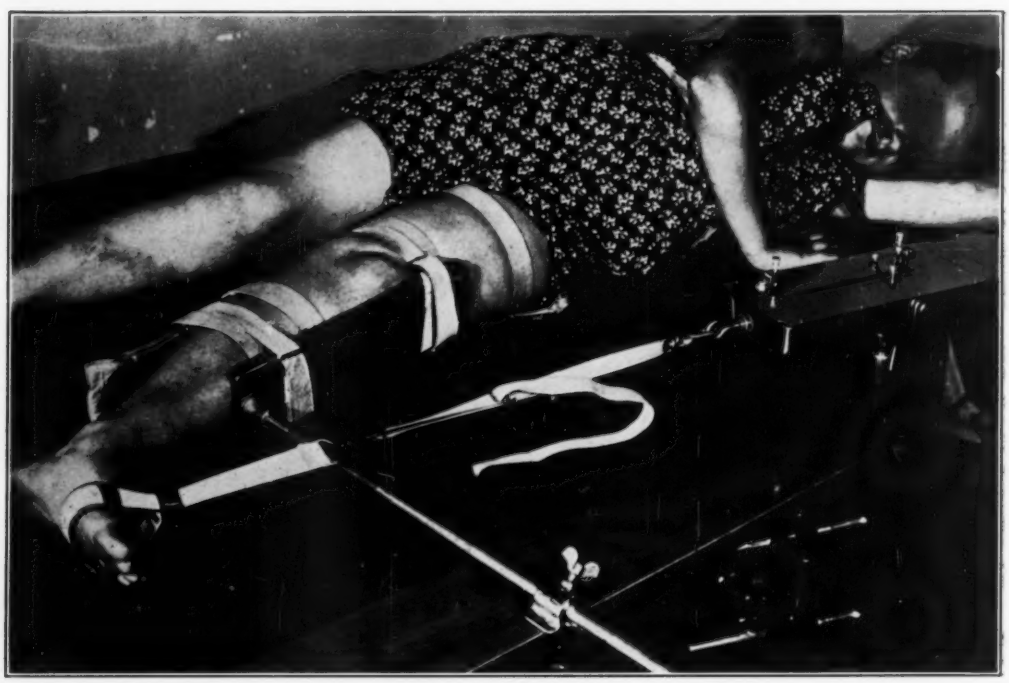

FIG. 10

Testing plantar flexion of foot. Knee is immobilized in extension. Recording of foot power begins with foot in maximum dorsiflexion.

ties of all patients was measured, as well as the length of the thighs and legs. It was found that the strength of the thigh muscles and leg muscles was not related to the length of the corresponding segments of the extremity. The length of each segment was then multiplied by the average circumference, but the results obtained bore no relationship to muscle strength. The volume of each segment of the lower extremity was then ascertained by a method similar to that used for determining the volume of a frustum. The following well known formulae were employed:

Volume = area × height. Area = π (3.1416) × R^2. Diameter = circumference ÷ π. The average area was determined by taking the measurements at each end of the segment and then dividing by two. The above calculations gave the volume of each segment. Disregarding bone, fascia, and fat, it was assumed that the results obtained were the volumes of the muscle mass. No definite relationship was noted between the volume and the muscle strength in each segment.

The strongest muscle group in the lower extremities was generally found to be the knee extensors. They were found to be definitely stronger than the antagonistic flexors in most cases. The plantar flexors of the foot were also found to be generally stronger than the dorsiflexors of the foot. The difference, however, was not great. The other antagonistic muscle groups of the lower extremities were found to balance each other more or less. The hip extensors were often found to be a shade stronger than the hip flexors; the hip abductors slightly stronger than the hip adductors; and the external rotators slightly stronger than the internal rotators.

The progress of infantile paralysis patients can be accurately charted by repeated examinations at stated intervals. For instance: Examination of a recent poliomyelitic patient disclosed the strength of the knee extensors to be seventeen pounds in one leg, and fifteen pounds in the other. (The average strength of this muscle group in normal children of the same age is about seventy-eight pounds.) After four months of treatment, a check-up examination revealed a gain in the involved muscle groups from seventeen to forty pounds in one leg, and from fifteen to thirty pounds in the other leg. A girl, eleven years old, with infantile paralysis involving the hamstring group was able to flex the knee with a strength of only ten pounds. (Thirteen normal eleven-year-old girls were able to bend their legs at the knee with an average pull of thirty-eight pounds.) The therapeutic value of electrical therapy, massage, and exercises was observed when, after less than four months of treatment, the stricken child had increased her knee-flexion power from ten to twenty-seven pounds. By detecting small differences of muscle strength at interval re-examinations, we will be able to control the form of therapy being given to the patient. The importance of determining the loss of even small amounts of strength in paralyzed muscles cannot be overemphasized. Excessive electrical stimulation, excessive massage, overexercise of paralyzed muscles, and improper splinting and bracing tend to weaken rather than strengthen these muscles.

Since minor changes in muscle strength are not readily detectable by the manual method of testing muscles, a muscle may gradually lose considerable power before the loss is recognized and the causative factor eliminated. When interval examinations with the scale method show a muscle to be weaker, the cause can be immediately investigated and corrected. By the scale method it will be possible to evaluate the comparative benefit derived from the various accepted forms of therapy presently in use. Small degrees of muscle imbalance, which if allowed to exist would produce deformities and contractures, may also be detected and corrected. In late cases of poliomyelitis, the value of accurate muscle testing may be important in determining indications for tendon transplantation.

The use of the scale method of testing muscle strength is not limited to infantile paralysis patients. The method can be employed in any condition of muscle weakness, if the full cooperation of the patient can be obtained, and he is willing to pull. It can be employed in cases of pseudohypertrophic muscular dystrophy, peripheral neuritis due to

injury or disease, congenital myatonia, and cases of quadriceps weakness following such operations as knee-joint arthrotomies. Although a fairly large number of patients have been examined, it is felt that further clinical work along this line should be carried on. It would be advantageous to have the work performed more generally, so that as many cases as possible in the convalescent stage of poliomyelitis could be examined. By this means, a universal method of examining patients might be established. The apparatus described is not only useful for examining muscle strength, but can also be employed for isolated muscle-group exercises. Therefore, it is of value in treating as well as in testing poliomyelitic patients.

The author wishes to express his appreciation to Miss Tova Schwartz and Miss Emmele Nansen for their aid in the technical examinations of the patients.

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REGENERATION OF THE PATELLA

A Case Report

BY W. P. CORRIERO, M.D., AND CHARLES AQUAVELLA, M.D., BROOKLYN, NEW YORK

From Kings County Hospital, Brooklyn

D.M., a colored female, sixty-three years old, was admitted on February 9, 1942, stating that on that day she had fallen on her right knee. Roentgenogram (Fig. 1) showed longitudinal and transverse fracture of the patella. Aspiration of the knee yielded 500 cubic centimeters of sanguineous fluid. The leg was put in Buck's extension, and swelling did not reappear. On February 26, after the abrasions on the skin had completely healed, the bone fragments of the patella were removed through a curved transverse incision. The joint was closed with No. 0 chromic sutures, and the tendons of the rectus femoris and the ligamentum patellae were sutured with No. 2 chromic mattress sutures. A posterior plaster mold was applied. Roentgenogram taken March 4, 1942 (Fig. 2) showed that the removal of the patella had been complete. The wound healed well. The patient was discharged on March 21, able to walk and to partially flex the knee.

FIG. 1

FIG. 2

FIG. 3

FIG. 4

Pathological report stated that all bone fragments of the excised patella could be fitted together, measuring 5 by 5 by 2.5 cubic centimeters, and evidence of neoplasm was not found.

On April 18, 1943, roentgenogram (Fig. 3) showed considerable calcareous deposit, presumably bone, at the site of the excised patella. On November 15, 1943, a firm bony patella could be palpated. The joint was stable in medial and lateral directions, and motion was from 80 degrees in flexion to 165 degrees in extension. The patient could walk about the room with only a slight limp, and could climb stairs with proper alternating stepping on the treads. She complained of pain in the knee, due probably to inability to fully extend the knee.

Roentgenogram (Fig. 4) revealed extensive regeneration of the patella and bony deposits in the patellar ligament.

TREATMENT OF FRACTURES OF THE OLECRANON BY FIXATION WITH STAINLESS-STEEL SCREWS

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It is impossible to reduce satisfactorily all fractures of the upper ulna without open reduction. Indeed, the only type of fracture which can be reduced under local anaesthesia and by external manipulation with towel clips, pins, and other devices is a simple transverse fracture of the olecranon where comminution is not present. Where there is comminution, especially in the articular portion of the bone, open operation is indicated,—first, to remove small articular fragments which might later interfere with joint function, and, second, to align properly the comminuted fragments.

Twelve cases of transverse fracture of the olecranon have been reduced without incision. Longitudinal fixation has been effected with long, slender, stainless-steel screws

FIG. 1

Transverse fracture of the olecranon prior to fixation.

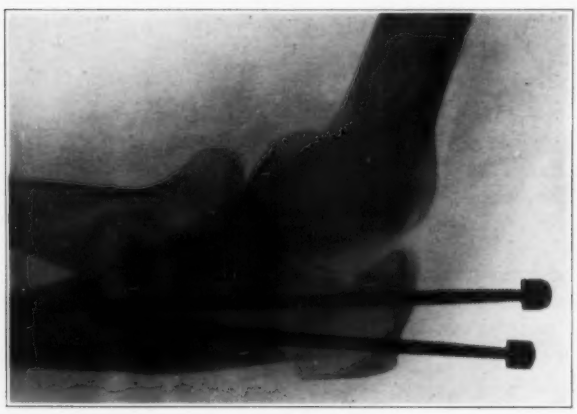

FIG. 2-A

FIG. 2-B

Lateral and anteroposterior roentgenograms of the same fracture eight weeks after fixation.

of a special design, introduced through puncture wounds posterior to the elbow. This type of screw has been previously described [1] and Figures 2-A and 2-B illustrate its use. The protruding head and proximal portion of the shaft of the screw facilitate subsequent removal (Fig. 3), which has always been done without discomfort to the patient and without anaesthesia. Reduction and initial fixation can be accomplished under local or general anaesthesia.

FIG. 3

Maximum of flexion obtainable in the same case ten days following fixation.

MacAusland has described a similar method, differing only in that the screw is shorter and is entirely buried beneath the skin at open operation. Rush and Rush have also utilized the principle of longitudinal-pin internal splintage in extensively comminuted fractures of the upper half of the ulna. Their pin is a modification of the Steinmann type, constructed of stainless steel, with the proximal end flattened on three sides to fit the clamp of a hand drill.

Patients do not suffer postoperative pain following fixation, so that extensive active motion is possible within a few days. Our patients have usually obtained 50 per cent. of normal range of elbow motion in four weeks. At the end of eight weeks, all but one of the screws are removed. The last screw is left in place for an additional four weeks.

In eleven cases of transverse fracture of the olecranon, active motion averaged 105 degrees at four weeks, 135 degrees at eight weeks, and all except two patients had full motion at twelve weeks. This rate of recovery of active motion is about twice that following open operation with internal wiring or other suture of the fragments. Eight patients returned to work eight weeks or less after injury. In one instance, that of a person with secretarial duties, active work was resumed the day after fixation. The other two patients were compensation cases and did not desire to resume work until the arm was "normal". As far as could be judged from the roentgenograms, osseous union was present in every case within eight weeks. The only other method which approximates this quick recovery is that of excision of the proximal fragment, described by Wainwright.

The twelfth patient was admitted, following non-union by cast treatment. After the fracture surfaces had been freshened at open exposure, fixation by the same technique was employed. Complete range of motion, delayed about six weeks, was finally achieved.

We have also utilized these screws for fixation of complete acromioclavicular separation, for fixation of the sternoclavicular articulation in delayed open replacement at this joint, and in certain depressed fractures of the tibial condyles.

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MULTIPLE RIB FRACTURES TREATED WITH A DRINKER RESPIRATOR

A Case Report

BY LIEUTENANT KRISTOFER HAGEN

Medical Corps, Army of the United States

In a recent critical review of war injuries of the chest, Edwards attaches a most unfavorable prognosis to that type of non-penetrating chest injury known as the "stove-in chest". After reviewing 1132 cases of chest injuries, Elkin and Cooper agree that the prognosis in this particular injury is poor. In the 'stove-in chest" most of the ribs are fractured bilaterally and the chest wall is rendered unstable. The causes of such an injury in war are various, whereas in civilian life, the most frequent cause is an automobile accident.[5]

PHYSIOLOGICAL ASPECTS

The physiological disturbances caused by this injury are many and profound. Shock is usually present, sometimes due to intrathoracic hemorrhage from a ruptured intercostal vessel, more often due to severe pain or disturbed chest physiology. Respiration is greatly impaired[7], and a condition resembling a large open pneumothorax is produced. Paradoxical respiration develops, as a whole segment of the chest wall is depressed during inspiration and forced outward during expiration. The dynamics of circulation are also affected. Normally the intrathoracic pressure is negative, fluctuating from -2.5 to -6 millimeters of mercury pressure during the respiratory cycle. The venous inflow to the heart via the thin-walled great veins of the chest and the auricles is assisted by the pumping action of these fluctuations in intrathoracic pressure. When the chest suffers a "stove-in" injury, much of the fluctuating negative intrathoracic pressure is lost. Cardiac circulation may be rapidly embarrassed. Another complication, observed by Key and Conwell, is paralytic ileus, associated with reflex spasm of the abdominal muscles.

TREATMENT

The principal considerations in the treatment of all chest injuries are: (1) the treatment of shock and hemorrhage, (2) the early restoration of normal cardiorespiratory function, and (3) the treatment of complications or sequelae. To accomplish the first and third of these purposes in the case of the "stove-in chest" involves routine surgical technique. One exception, perhaps, is that in treating shock a comfortable propped-up position or sitting posture is preferred to the usual Trendelenburg position. The difficulty in accomplishing the second purpose, however, may not be so easily solved, as may be reflected in the variety of procedures recommended.

Many authors[1, 4, 5, 6, 15] suggest immediate immobilization of the chest wall with adhesive strapping or swathing, applied from below upward, with the chest in full expiration, supplemented with oxygen by the most convenient method and other supportive measures. Roberts and Tubbs emphasize the danger of aggravating the patient's condition by early strapping of severe chest injuries of this type during the initial period of shock. They advocate rolling the patient onto the affected side until shock is controlled; they find delayed adhesive strapping surprisingly effective, even when as many as eleven ribs are fractured on one side. According to Blades, one adhesive strip encircling the chest at the level of the costal margins anteriorly is just as effective as multiple strips. On the other hand, Key and Conwell, and Speed advise limiting the strapping technique to cases in which ribs below the fourth rib are fractured; they consider strapping unwise in more extensive multiple rib fractures. Others[7, 9] favor infiltration of the affected

intercostal nerves with procaine. Bohrer infiltrates the intercostal nerves and considers strapping of any "severely crushed" chest unwise, adhering rather to bed rest, sedation, oxygen, and other conservative measures.

Surgical intervention in severe cases to elevate depressed rib fragments and to immobilize the fractures with sutures or wire is preferred by some.[7, 13] A method of applying hook traction to the sternum at the level of the third interspace has been suggested [10], as has traction by sterile towel clips or wires applied directly to the involved ribs.[17]

Gray suggests that, if tight dressings, light sandbags, or similar measures do not immobilize the chest sufficiently to permit normal breathing, a respirator may be used "so that the respiratory act may be controlled". Watson-Jones also finds the respirator useful in severe cases.

The following case of severe crushing injury to the chest is reported, because of the dramatic improvement produced in the patient's condition by the use of a Drinker respirator, and because of the interesting physiological principles involved.

CASE REPORT

W. S., a Cherokee Indian, forty-six years of age, was admitted to the William J. Seymour Hospital, Eloise, Michigan, on July 18, 1943, at 8:45 in the evening, one hour after having been involved in an automobile accident. His car had overturned and a 285-pound passenger had fallen directly onto his chest. He was given a quarter of a grain of morphine sulfate at the scene of the accident by a physician. Upon admission to the Hospital, he complained of difficulty in breathing and pain in the chest, but felt well enough to request his discharge. While still in the admitting room, however, his symptoms became rapidly worse, and he consented to hospitalization.

Physical examination revealed a short, stocky, moderately obese male Indian of middle age in respiratory distress and with moderate cyanosis. Rectal temperature was 100.6 degrees, the pulse 120, the respiratory rate 48, and the blood pressure 120/82. There was a small but deep puncture wound of the right arm and a long superficial abrasion of the skin along the right posterior thoracic wall. The wall of the chest moved paradoxically with respirations, especially on the left side. The entire thoracic cage was somewhat immobilized by spasm of the intercostal muscles, and respiratory effort was chiefly abdominal. Bony crepitus and marked tenderness were elicited on both sides of the chest, most marked on the left. The patient could not tolerate percussion of the chest. Auscultation was unsatisfactory, but revealed some coarse rhonchi on the left and sounds suggesting the presence of fluid on the right. The heart sounds were normal. The abdomen was slightly distended, but otherwise normal.

The patient was given 1500 units of tetanus antitoxin. The puncture wound of the arm was treated and he was put to bed. Two hours after admission, he had become extremely dyspneic, cyanotic, restless, and uncooperative, and had had periods of semiconsciousness. Physical examination and fluoroscopy revealed the probable presence of fluid in the left pleural cavity, but a thoracentesis yielded no fluid. He was placed in an oxygen tent, which was adjusted to provide eight to ten liters of oxygen per minute, and was given one grain of codeine sulfate hypodermically. At three in the morning he was rational and cooperative, but continued to be dyspneic and moderately cyanotic.

Roentgenograms of the chest taken later in the morning (Fig. 1) showed fractures of the second to the eleventh ribs in the right posterior axillary line, the fourth rib being fractured in two places. There were also fractures of the second to the twelfth ribs on the left, with over-riding of the second, fourth, and fifth rib fragments. Gaseous distention of the stomach was noted.

Wangensteen suction was instituted to relieve the upward pressure of the dilated stomach, but despite this measure and the continued increased administration of oxygen, the patient became steadily more dyspneic and cyanotic. He complained of severe interscapular pain. His temperature remained elevated (Fig. 2), the blood pressure rose rapidly to 228/130, the pulse to 132, and the respiratory rate to 64 per minute. The advisability of some immediate operative procedure was considered, but abandoned in favor of placing the patient in an available Drinker respirator. This was accordingly done at 8:30 on the evening of July 19, about twenty-four hours after the injury. The treatment with oxygen and the Wangensteen suction was continued. The respirator was adjusted to provide a *negative* pressure of 20 millimeters of mercury intermittently at a rate of 36 cycles per minute. The valves were carefully adjusted to *avoid positive pressure*, inasmuch as it was felt that the patient needed only expansion of the chest by artificial means. Within an hour after being placed in the respirator the patient's color and general condition showed marked improvement. By the next day his blood pressure had decreased to 182/102 and his pulse to 100 per minute. His temperature rose to 102 degrees orally. He was able to do without the oxygen tent and to have the rate of the respirator reduced to 28 per minute (Fig. 2). Two days later he was afebrile, had a blood pressure of 136/80, pulse rate of 80 to 100 per minute, and felt comfortable with the respirator set at 21 per minute.

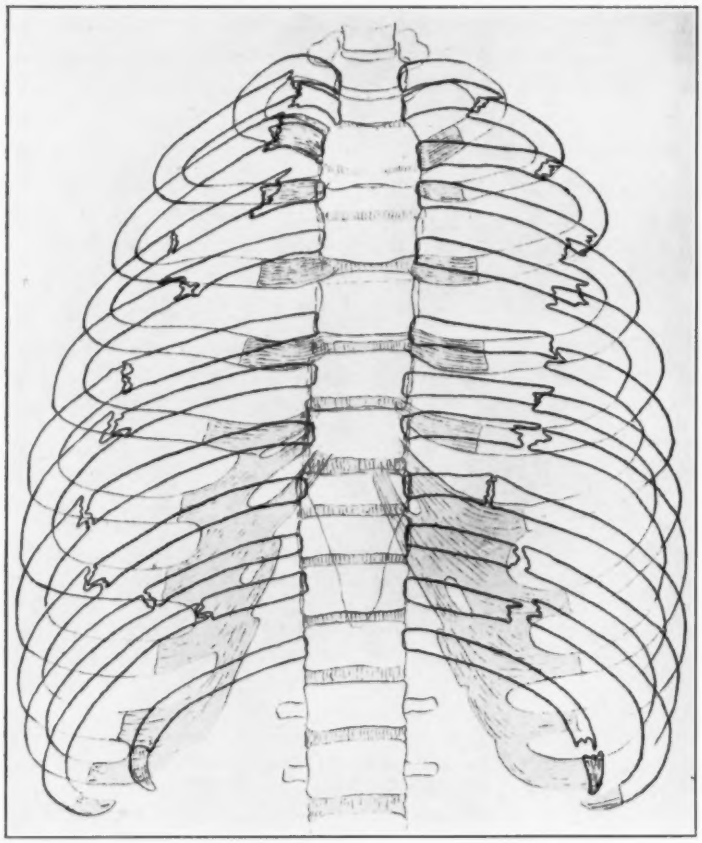

FIG. 1

Diagram of rib fractures adapted from x-rays.

On July 26, after one week in the respirator, he was removed for several hours, but as it was noted that his respirations, pulse, and blood pressure began to rise promptly (Fig. 2), he was returned to the respirator and kept there constantly for a total of ten days, when a schedule of gradually increasing periods of time outside of the respirator was instituted. By August 7, three weeks after the injury, he could breathe without the aid of the respirator. Chest-expansion exercises were instituted and he was discharged in fair condition on August 27. At the time of discharge roentgenograms showed early callus formation at the sites of the fractures, thickening of the left pleura, and some interlobar pleurisy on the right.

He was last seen in the Out-Patient Department on March 31, 1944, and he stated that he felt very well and had been able to carry on full-time work as a metal polisher since October 1943. He weighed 180 pounds, had a temperature of 98.6 degrees, a pulse rate of 76, respiratory rate of 20, and blood pressure of 186/100. Chest expansion was two inches at the level of the fifth rib. Vital capacity was 2850 cubic centimeters in the standing position and 2600 cubic centimeters in the sitting position, which was calculated to be about 70 per cent. of normal for his height and weight. Roentgenograms showed good bony union of all fractured ribs, though there was persistent overriding of the fractures of the second, third, fourth, and fifth ribs on the left. The lung areas were clear.

COMMENT

This case presents several very interesting features. Unlike most persons similarly injured, the patient never seemed to be in shock. On the contrary, he did develop a hypertension during the first few hours after injury. A possible explanation for the hypertension is the profound retardation of circulation produced by the loss of normal, fluctuating, negative intrathoracic pressure.

The slowed circulation must have involved also the renal circulation and produced a renal ischaemia with a consequent hypertension, comparable to the Goldblatt mechanism. The hypertension was quickly relieved when the cardiorespiratory function was restored to normal by the respirator.

An interesting and perplexing finding was observed months later, however, when the patient, apparently fully recovered from the injury, was found to have a moderate hypertension. Of course, this may be unrelated to the injury, inasmuch as the patient was of the habitus and age group in which hypertension most often develops. The finding should not be overlooked. Could it be due to delayed kidney damage?

The patient improved so dramatically after being placed in the Drinker respirator that the following conclusions were reached:

1. Wherever a Drinker respirator is available, it is a much *simpler treatment to apply* than other procedures used to accomplish stabilization of the thoracic wall.

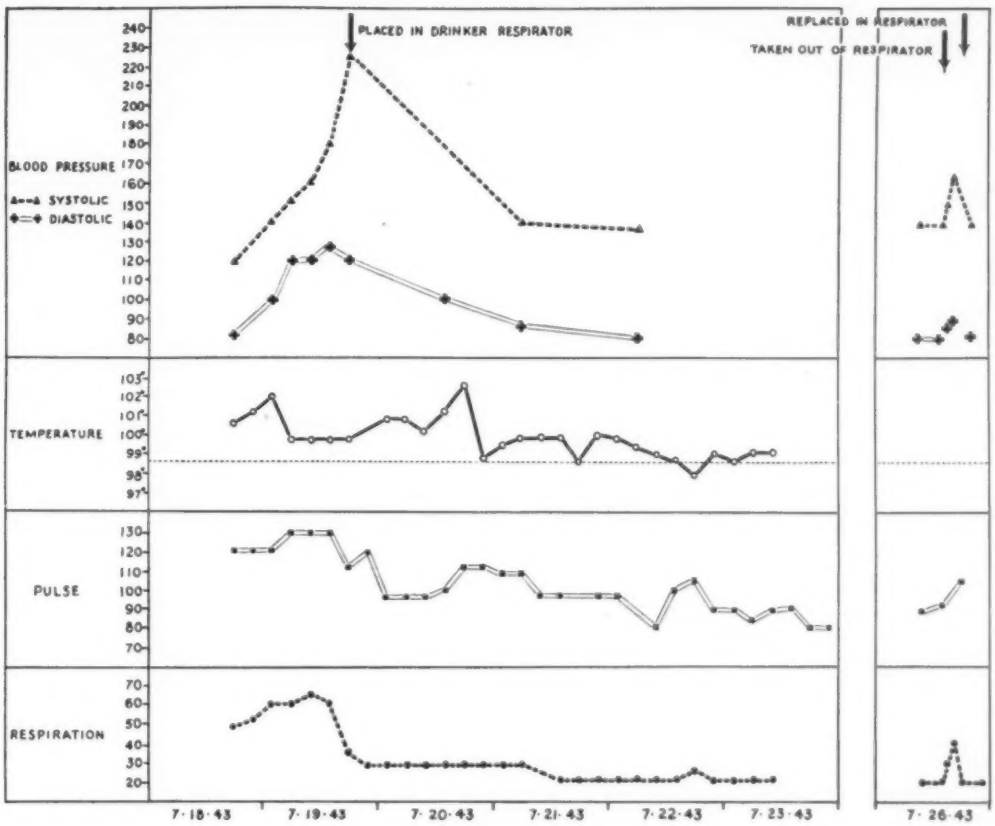

FIG. 2

Clinical Chart.

2. It *avoids the obvious risks of surgery* in patients who are already critically ill, and the danger of infection associated with traction hooks in sternum or ribs.

3. It exerts a *gentle, non-mechanical expanding effect* on a thoracic cage which is already compressed and is thus obviously superior to any binding or taping measures, which tend to compress the chest further.

Obviously one cannot generalize and say that the respirator is the only treatment for the "stove-in chest" injury. Every patient with a seriously injured chest requires individual consideration, but it would appear that the use of the Drinker respirator, wherever available, deserves more consideration than it has heretofore received in the treatment of this type of injury.

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A RETROSPECTIVE COMMENTARY ON THE CAMPAIGN FOR THE ESTABLISHMENT OF THE POSITIVE STANDARD OF TREATMENT FOR FRACTURE OF THE NECK OF THE FEMUR

BY ROYAL WHITMAN, M.D., NEW YORK, N. Y.

Positive treatment of fractures at the hip was made practicable by the substitution of natural for artificial mechanics. For since the neck of the femur projects laterally from the shaft, splinting and traction can at best appose displaced fragments only in a lateral and, therefore, insecure relation.

The inadequacy of the means at command to provide the stability essential to repair was clearly demonstrated by Sir Astley Cooper early in the last century. He contended that since it was impossible, even for a few hours, to preserve exact apposition of the fragments, the surgeon should not be held responsible for a result over which he could have so little control.

His pronouncement established the *negative* standard, which determined the character of conventional practice for a hundred years. Surgeons long maintained that restoration of form and function was rarely to be attempted or even sought, and that the first indication was to save life; the second to secure union; the third to correct or diminish displacements.

The first of these results could be attained by propping the patient up in bed with the limb between sandbags. After a month the patient would be encouraged to use the limb as much as possible, since union was not aimed at. Union seemed to be dependent on adhesion or impaction of the fragments, and actual treatment was usually limited to making only as much reduction of the deformity as could be expected from moderate traction and immobilization by cushions or by a fixed dressing.[4] It was taken for granted by all that a broken hip entailed permanent disability, and in many cases death.[12]

No matter whether the fracture took place within or external to the capsule, or whether it united by ligament or by bone, shortening of the limb and lameness were considered to be inevitable results. One writer even held that, "If he [the patient] escapes with his life, he has to be contented with loss of function, loss of symmetry and equipoise, and is often obliged to go about crippled".[2]

The character of the disability is illustrated by a report on the final results in eighteen cases that had received hospital care by extension in bed without direct fixation. Five of the patients had never attempted to walk; eight used two crutches in locomotion; one used a crutch and a cane; one used two canes; two used a cane; and one wore a high shoe, but walked without support.[21]

This introduction has been drawn from representative sources in order to present fairly the background on which the anatomical method, as the exponent of surgical principles and, therefore, of radical reform, was projected. It will also serve as a point of departure from which to estimate progress toward the establishment of the *positive* standard.

The inception of the anatomical method was coincident with the identification of fracture of the hip in childhood, an injury unknown to authority and, therefore, beyond its jurisdiction. The typical history of such a case was that of a child who had fallen from a fire escape. The fracture was not recognized, but, as it was incomplete, repair had followed. Months later the child was brought to the hospital for a persistent and increasing limp, supposed to indicate hip disease. At this time (1890) the x-ray was not available for diagnosis, but the elevation of the trochanter, the outward rotation of the limb, and the evident limitation of abduction by bony contact, indicated a downward and backward displacement of the femoral neck, afterward called coxa vara.

This analysis of the disability was enlightening, since it demonstrated that the chief factor in the limp, the inevitable sequence of the fracture in adult life, was not shortening of the limb, to which it had been attributed, but restriction of abduction. It was evident, therefore, that restoration of the normal relations of the hip joint was the only remedy.

This was accomplished indirectly by an osteotomy at the base of the trochanter, so that by abducting the limb and rotating it inward, the shaft was brought into proper relation to the neck; for under normal conditions, the position of the head would require a corresponding abduction and inward rotation of the shaft.

A plaster spica was then applied and retained until union was complete. Therefore, when the limb was brought to the mid-line, in apposition to its fellow, the angle of the neck was automatically restored, and functional cure was established.

The success of this first essay in reconstructive mechanics clearly indicated that, if one had the opportunity to treat the fracture in the plastic stage, the deformity might be corrected directly by the same manoeuvre,—namely, by forcible adjustment of the shaft to the articulating fragment fixed in the acetabulum.

On further investigation of the mechanism of the joint, it appeared that the anatomical method would be equally effective for the complete or typical fracture, long considered the keystone of the negative standard. If the fragments were brought into the same plane by traction on the limb and inward rotation, full abduction by tension on the capsule would adjust them; and the security of end-to-end apposition would be supplemented by the impingement of the base of the neck on the rim of the acetabulum. Furthermore, in this attitude, there would be complete suppression of muscle action, an agent of deformity that Sir Astley Cooper had found impossible to control.

This experience clearly indicated that the primary essential of functional repair in all types of fracture at the hip was the restoration and maintenance of the femoral angle. To emphasize this conclusion, the method by which it was accomplished was called the "abduction treatment".

Since it was evident that, from the mechanical standpoint, a method effective in

childhood would be equally so in adult age, a new field of therapeutic endeavor was opened. At the outset it was encouraging to note that the established inhibitions to positive treatment were in the nature of a defense reaction to therapeutic inadequacy. The typical patient of the textbooks was aged and feeble, but the vigorous subject fared no better as far as technical treatment was concerned. It was assumed that the complete medial fracture was practically incapable of repair, but its recuperative capacity had never been tested by opportunity. It was assumed that the restraint required for positive treatment of the fracture would endanger life. It appeared, however, that in fatal cases, the patient usually survived for several weeks, to die from "exhaustion", of which the chief contributing factors were hypostatic congestion of the lungs and infected bed sores. The mobility of the plaster spica, and the security of the anatomical splinting suggested effective remedies against these complications. The patient was placed on an inclined plane by raising the head of the bed one foot or more, and was turned at intervals from side to side and completely over to the ventral position. Furthermore, the security of the support permitted transportation to the open air or elsewhere, with the inspiriting prospect of eventual recovery, thus providing a moral as well as a physical prophylactic for the conventional exhaustion.

Since the object of positive treatment was to restore function, the initial opportunity for its attainment was supplemented by equally adequate after-care. It was recognized that repair of the medial fracture, since it was an interstitial process unaided by external callus, must be slow and precarious, dependent upon rest, uninterrupted and prolonged. Furthermore, because of its exposed position, the resumption of activity should be strictly regulated to the stability of repair. During the recuperative period, the first concern should be the maintenance of the range of abduction by routine manual "stretching" outward to the primary position until voluntary control had been established. Finally, the patient should be trained in the equal gait, since the test of success was no longer "to save life" nor "to get union" but a symmetrical gait.

Thus it will appear that the abduction treatment was developed by successive steps, in logical sequence, upon a secure foundation, and followed to its legitimate conclusion.

Established teaching offered no incentive to efficiency and, therefore, no penalty for incompetence and neglect. Naturally, the abduction treatment, the exponent of the positive standard and consequently of radical reform, made slow progress against the weight of authority, inertia, and technical unpreparedness to meet its requirements. However, in the lapse of years it has come into general use, and experience has amply demonstrated its comprehensive practicability.

Of 441 cases of medial fracture treated by this method, 126 of the patients were over seventy, and fifty-seven were over eighty years of age, yet the death rate was only 7 per cent.

As to the capacity of the medial fracture for repair, a competent observer concludes that union should be attained in 65 per cent. of the older class, and in 90 per cent. of those less than sixty years of age.[7]

Yet in a group of seventeen patients over seventy, union occurred in 78 per cent.[14]

Formerly, as has been noted, a sharp distinction was made between the intracapsular fracture, in which the patient was the first consideration, and the extracapsular type for which protective treatment might be of service in promoting repair.

The relative frequency of the two forms is indicated by a report of 264 cases treated by the abduction method: 172 were intracapsular with union in 67.5 per cent.; ninety-two were extracapsular with union and good function in all,—approximately 80 per cent. of the group. The mortality rate was 6 per cent.[9]

Now that all types of the injury are treated by the same method and with the same purpose, namely the restoration of normal locomotion, the fracture may be considered as an entity. A direct comparison with the nailing method may serve to clarify what

appears to be a general misapprehension of the relation of one method to the other as representative of the positive standard.

Nailing the fracture was introduced during the last century as the only means of fixing the fragments.[10] The method has undergone several modifications in technique in recent years.[1, 8, 13] Its most attractive feature is the relative freedom from restraint that the security of the internal splint permits.

From reports on the nailing method, one might infer that secure fixation of the fragments assures a fairly free and painless range of controlled motion. Actually, since the joint is involved in the process of repair, it is sensitive to unguarded movement. Sympathetic muscular protection restricts the voluntary range, and there is a persistent tendency toward the protective attitude of flexion and adduction, a tendency that would be favored by locomotion and confirmed by the sitting position in the wheel chair. Thus the abduction treatment has become the representative of conservatism by maintaining rest during the initial stage of repair as the essential factor in the restoration of function.

The nailing method can qualify as an alternative to the abduction treatment only in a restricted sense. It is not adapted to fractures at the base, since the cancellous structure of this region cannot assure security for the nail, and because the trochanter may be involved in the injury. In this type of fracture, the capacity for repair is adequate, and there is even a tendency to callus formation to the extent of embarrassing function. Thus motion is contra-indicated, even if the stability of the internal splint were assured.

For these fractures, the indications for treatment should be evident,—namely, to restore the femoral angle and to maintain the attitude of abduction. For this purpose the mechanical advantages of the abduction method should be obvious.

Considered as an alternative to the abduction treatment, there are intrinsic and incidental drawbacks to the nailing method that must be reckoned with. A certain shortening of the femoral neck during repair is not unusual, and a number of cases have been reported in which spontaneous extrusion of the nail has permitted union which otherwise would have been prevented.

Partial necrosis of the head of the femur may occur after union, to which functional activity may have been a predisposing factor. The same inference applies to secondary arthritis. Depression of the femoral neck to the degree of embarrassing function is another mishap which must be attributed to premature weight-bearing.

The most illuminating paper bearing upon the question at issue, that has come to my notice, is an analysis of the final results in seventy-five cases of intracapsular fracture treated by the Hey Groves method of pinning in the Bristol Fracture Service.[6] The fragments were adjusted by manipulation under x-ray supervision, while the limb was supported in an attitude of 15 degrees of abduction and slight inward rotation by a seated nurse who exerted slight traction on the flexed leg by leaning backward. Five to seven roentgenograms were taken to assure the adjustment of the fragments and the proper direction and depth of insertion of the nail. Movement of the limb within a few days was encouraged. Direct weight-bearing was not officially sanctioned for three months, but locomotion on crutches was resumed at a much earlier date.

Fifty-two of the seventy-five patients were personally examined. Seventeen were dead and six were not available for tabulation. The results were classed as satisfactory in 50.7 per cent. Failure was attributed to defective technique in seven cases and to suppuration in three. In two cases the neck was shortened, but spontaneous extrusion of the nail had permitted repair. In four instances there was necrosis of the head of the femur after union of the fragments.

As to function, it was stated that from 80 per cent. to 100 per cent. of motion was retained, but as there was a certain degree of varus or valgus deformity in three cases, complete restriction of abduction in one, and of inward rotation in another, it is evident that success did not imply a symmetrical gait.

Accepting this report as fairly representing the nailing method as a routine and independent procedure in competent hands, it may be suggested that the failures attributed to defective technique might have been lessened, if the anatomical method had been utilized to adjust the fragments, which in full abduction and extension lie in a horizontal plane, fixed end-to-end by capsular tension against the resistant pelvis. Thus they should not be displaced or jarred apart by the impact of the nail. Relatively speaking, the whole procedure may be completed in a few minutes, as contrasted with the prolonged manipulation required for tentative adjustment. On this point I can speak from personal experience. Many years ago I made a brief trial in spiking, only for the purpose of assuring greater security, but I soon discarded the practice as unnecessary.[17]

It may be assumed that the functional results might have been better if the resumption of activity had been adapted to the resistance of stable repair, rather than to what Brailsford refers to as the false sense of security which the nail gives.

This analysis seems to support the conclusion that the nailing method should be classed as a complement to the abduction treatment, in the sense that anatomical mechanics should be utilized to adjust the fragments. It is of value in a special type of fracture, as an internal splint in relieving the patient from the restraint of a comprehensive support. But it must be remembered that its use as a prop for weight-bearing and as a pivot for enforced movement during the critical period of repair is a concession to the patient at the expense of the functional result.

The final step in the expanding scope of anatomical mechanics was in the treatment of ununited fracture at the hip, a common, crippling, and often a painful and progressive disability. The loss of resistance to weight-bearing induced friction and disintegration of the fragments, upward displacement of the shaft, and the deformity incidental to persistent flexion and adduction of the limb.

The problem in treatment, therefore, was to restore stability in weight-bearing and to assure the maintenance of abduction, essential to serviceable locomotion. This was accomplished by the reconstruction operation.[18] The trochanter with its attached muscles was separated from the shaft in the line of the neck, thus providing a sufficient area of bearing surface. The head of the femur was removed, and the improvised neck securely implanted in the acetabulum by abducting the limb to the required degree. The trochanter was then drawn down as far as its attachments would permit, and implanted on the outer border of the femur. A plaster spica was applied, holding the limb in approximately twenty degrees of abduction and full extension. Eventually this was replaced by a short spica, and locomotion was resumed. When the security of the transplanted trochanter was assured, the support was removed and a routine of manual stretching of the limb outward to its original position was instituted, and continued until voluntary control had been established.

The distinctive advantage of the reconstruction operation in the class of cases for which it was designed was that, since it was based on sound mechanics, a satisfactory result might be assured in a definite time, as contrasted with procedures in which it was dependent upon the uncertainties of repair.

The principles of the reconstruction operation have been applied with success in a number of different conditions resulting from injury or disease,[20] and it should be a preliminary to all forms of arthoplastic procedures in which shortening of the femoral neck and contact of the trochanter with the acetabular rim limits the range of motion essential to satisfactory locomotion.

The reconstruction operation in completing the therapeutic control of this refractory fracture brought the campaign for the establishment of the positive standard to a successful conclusion. As no claim has ever been made for a share in the inception and development of the method by which it was accomplished, it would seem to qualify as a personal contribution to surgical progress.

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ERNEST WILLIAM HEY GROVES, M.D., M.S., F.R.C.S.

1872–1944

In the passing of Hey Groves, The British Orthopaedic Association has lost one of its most distinguished members and a former President. His name is known the world over as that of a pioneer who has clearly left his mark, not only upon orthopaedic surgery, but directly and indirectly upon the art and science of surgery in general.

Hey Groves was the son of an English civil engineer, Edward Kennaway Groves, and was born in India in 1872. At the age of three, when his father retired, the family settled in Bristol.

His medical education was received at St. Bartholomew's Hospital, London, where, having taken the degree of Bachelor of Science, while still a student, he started his teaching career as a demonstrator ["instructor" in the United States] of biology. This experience stood him in good stead, for he later became an outstanding teacher of surgery. Following his graduation in 1895, his first interests were in obstetrics and, after experience in different parts of England and a period of study at Tübingen, he settled in general practice in one of the outer Bristol suburbs. But he did not stay long in general practice. His search for surgical knowledge and experience was insatiable.

In 1896 he married Miss Frederica Anderson, who had been a nurse at St. Bartholomew's, and together they made their home into a private hospital. Here, with the help and encouragement of his wife, Hey Groves established his reputation as a surgeon. To his students he used to say that this episode in his life had its darker side, for tales were spread abroad that "Butcher Groves lured women into his home, operated upon them, and would not remove their stitches until they had paid their money". In spite of such petty nuisances, he was indefatigable, for, in the midst of his busy practice, he was able to attain high academic honors.

In 1905, having taken the Fellowship of the Royal College of Surgeons of England and the degree of Master of Surgery of London University, he was elected to the staff of the Bristol General Hospital. While thus engaged in surgery, he was still able to work as senior demonstrator of anatomy in Bristol University. He never deserted general surgery, but his mind soon tended to concentrate upon the mechanics of bone and joint surgery. He was indeed most ingenious and skillful, and "Hey Groves" splints and appliances became a byword. Indeed his early work anticipated much that followed in the field of orthopaedic surgery. Before the days of the Smith-Petersen nail, he fashioned pins from beef bone and horns for use in fractures of the neck of the femur. In 1913, he described transfixion pins which, passing through fragments, were fixed to external bars, thus with Lambotte anticipating Roger Anderson, Haynes, and others who later perfected this principle. These pins were again used by him in the treatment of gunshot injuries of bones; he wrote a primer on this subject in 1915. During the War of 1914–1918, he served in the Royal Army Medical Corps, and was sent to Egypt in charge of the surgical division of a general hospital. Illustrating his resourcefulness, it is related that, on setting out for Alexandria with other R.A.M.C. officers, he found that none could go aboard ship unless properly dressed in spurs; whereupon he managed to acquire a rusty pair at a marine store, and, having himself embarked, tossed them ashore repeatedly for the use of each of his colleagues in turn.

On November 28, 1917, he was one of that small group of surgeons who met together at dinner at the Café Royal in London to consider what steps should be taken to found an association of British orthopaedic surgeons. At that time Hey Groves did not regard himself as an orthopaedic surgeon in the accepted sense of the term; but, at the invitation of Robert Jones, he had already entered the fold by taking surgical charge of the Military Orthopaedic Centre at Bristol. His intrusion into orthopaedic surgery was viewed by certain purists of the older school with considerable misgiving, and, by a narrow doctrinaire interpretation of what constituted a "real" orthopaedic surgeon in the year 1917, his name was omitted from the list of eighteen surgeons invited to become foundation members of the new Association. It was characteristic of the man that he showed no open resentment at this most unfortunate action. It was not long before the Association made amends by sending a special invitation to Hey Groves to join in the capacity of an original member. From that time on, he became a loyal and powerful advocate of the cause of orthopaedic surgery; and, during the earlier years of the Association, this small specialist body gained prestige from the fact that one of its most distinguished active members held a University Chair of Surgery, was the Editorial Secretary of *The British Journal of Surgery* and later became a Vice-President of the Royal College of Surgeons. It was clearly fitting that Hey Groves should in due course be chosen as President of The British Orthopaedic Association, and his second year in that office (1929) was notable in the annals of the society as the occasion when a strong contingent of The American Orthopaedic Association came to London to take part in a joint meeting with their British colleagues. The following year Hey Groves became President of the Association of Sur-

E. W. HEY GROVES

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geons of Great Britain and Ireland, thus attaining to the dual honor which Robert Jones had previously achieved, and thereby forging another link between general and special surgery.

The British Orthopaedic Association is now, by common consent, the most vigorous of the special Associations in Great Britain. It has a large and ever-growing membership, but there has been no schism. Orthopaedic surgery remains within the fold of surgery as a whole, and the tradition of unity founded by Robert Jones and fostered by Hey Groves still endures.

At Bristol, Hey Groves had been promoted to the Chair of Surgery in 1922. An old student writes: "He had a vivid character, full of imagination and energy; he was an excellent teacher who brought a great sense of humor to his well attended ward rounds and operations. He was naturally very popular among the students; for, youthful himself, he was very fond of young company and always enjoyed a party, particularly dancing. Not infrequently his students, staff, and ward sisters were invited to join him—he was so charming." Some of these students had other reasons to be grateful, for not a few keen men were helped financially through difficult periods of their student life and the following days.

As a writer, Hey Groves was prolific; several standard textbooks on surgery for students and nurses came from his pen. For the practising surgeon, his concern was no less great, particularly his desire to advance the treatment of fractures and operative technique. "The Modern Treatment of Fractures", written in 1916, was followed by many authoritative articles on these themes, and in 1935 he published his translation of Lorenz Böhler's work, of which he was a wholehearted supporter. In his foreword, Hey Groves emphasized the fundamental principles which Böhler had demonstrated: "the necessity for unity of control, loyal and efficient team work, accurate knowledge of the after-results, and meticulous attention to detail".

Throughout his life, both in surgical practice and in teaching, his mind was alert to the needs of the "everyday" problem, the thorough teaching of the student and younger surgeon in groundwork, and the simplification of methods for the safety of the patient. No better example of this can be found than in that product of his later period, the "Hey Groves Introducer" for the Smith-Petersen nail, which one of his followers has described as "making a very difficult operation simple".

In all this, sufficient would be found to place the name of Hey Groves high in the history of surgery during the past fifty years. In addition, however, we must note the special part he has played in scientific journalism, and in the advance of surgery through the distinguished *British Journal of Surgery*, with the origin of which he was so closely concerned, and whose destinies he so largely directed as editor for twenty-eight years. In 1941, when he was forced to retire, owing to a period of ill health, aggravated by enemy action, the Journal was able to say:

"During all this time the services of our Editor have been remarkable and steadfast and his robust honesty of purpose and tireless work have served the Journal well. A wide knowledge of world literature and foreign travel have given Groves a breadth of outlook which has been of great value. Our present position entitles us to claim that we rank very high among the leading surgical journals of the world, and it is not too much to say that this enviable position is very largely due, not only to the work, but to the outlook and the sustained interest of our first Editor."

Certain it is that *The British Journal of Surgery* has set a very high standard, not only in its format and technical production, but in the care which obviously for so long has been spent upon its editing. In that Journal's first twenty-eight volumes, will be found for future readers a worthy monument to Hey Groves.

SIR HENRY GAUVAIN, M.D., M.CHIR. (CANTAB.), M.D. (HON.) MELB., F.R.C.S.

1878–1945

In the year 1908, there was founded at Alton in the English County of Hampshire, the Lord Mayor Treloar Cripples' Hospital. The founder, Sir William Treloar, a philanthropic man of business, chose as Resident Medical Officer a young man, thirty years of age, who had only recently completed his house appointments at St. Bartholomew's Hospital, London. Sir William planned his hospital to care for the crippled children of London, whose need had so greatly impressed him. The plans were laid with care, and have borne abundant fruit in the fine modern orthopaedic hospital which now bears his name, caring for a far wider community than was dreamed of by its founder. That such development and expansion proved possible can in large measure be attributed to the vision, energy, and enthusiasm of that young man of thirty, who later became Sir Henry Gauvain, the Hospital's Medical Superintendent, and who for thirty-seven years labored to develop and expand the work of the Hospital, so that it has acquired an international reputation.

It is difficult now to realize the indifference and lack of interest in crippling conditions—particularly surgical tuberculosis—that existed forty years ago. Gauvain, from the first, made surgical tuberculosis his especial study, and in the course of a few years materially altered the pessimistic attitude characteristic of those days toward all forms of bone and joint infection. Deliberate and planned conservative treatment of surgical tuberculosis was scarcely practised in England at that time. Indicative of the apathy with which Gauvain had to contend was the comment of a distinguished consultant member of the Medical Board which Sir William Treloar had appointed to guide him in developing the Hospital, who said of Gauvain's request for provision of a sterilizing plant: "Of what use are sterile dressings for cripples?"

Gauvain, born in Alderney of an old Channel Island family, had early acquired a love and appreciation of the value of the sun and the sea. A visit to Berck-sur-Mer, where the conservative treatment of surgical tuberculosis had already been practised for many years, quickly led Gauvain to realize the importance of the open air and the sun in the treatment of the disease.

From the first, therefore, Gauvain stressed, in articles and to the many students and medical men who soon began to come to Alton, that the surgical tuberculous lesion was but a local manifestation of a general disease, and that no form of local treatment could be successful unless it were accompanied by "all possible measures to improve the patient's general health and increase his powers of resistance to tuberculous disease". Gauvain was a man of vision and originality, and he determined to interpret his principle of full and active conservative treatment of the patient as a whole in its widest and most complete sense.

He studied hospital planning and persuaded the Trustees of the Hospital to build at Alton a hospital which is a model of hospital design for the open-air treatment of children, with the most complete surgical facilities. Land was acquired at Hayling Island for a seaside branch, so designed that bed as well as ambulant patients could benefit by sea-bathing as a form of treatment.

SIR HENRY GAUVAIN

Gauvain realized early that no plan of general treatment for a chronic disease in childhood could be adequate, which did not also cater to the mind. An experimental hospital school—the first of its kind in England—was sanctioned by the Board of Education in 1912. Lloyd George, then President of the Board of Education, was so impressed with the importance of the work that he decided that grants should be given to extend this type of education throughout the country.

By 1920, when Gauvain received the honor of knighthood, it is no exaggeration to say that his work had led to an entirely new outlook on the part of the profession toward the possibilities of the non-operative treatment of surgical tuberculosis and the prognosis of the disease.

Gauvain did not neglect the local treatment of the tuberculous lesion. He designed a number of splints and appliances for the fixation of the lesion and the prevention or correction of the deformity. All such appliances were governed by the principle that "the simpler the appliance employed, the greater the comfort to the patient; and the fewer the complications in the apparatus, the better the result will be". He was responsible for introducing the technique for making light moulded splints of celluloid-impregnated muslin, so valuable for use in tuberculous disease in children. To see him apply and mould a plaster spica to a child was to realize that for him it had to be artistically satisfying, as well as mechanically efficient.

From Calvé, at Berck-sur-Mer, Gauvain learned the technique of the aspiration of tuberculous abscesses, particularly of the psoas abscess. Realizing the value of the method in preventing sinus formation and secondary infection, Gauvain practised and endeavored to popularize the method in England. Surprisingly, the practice of aspirating psoas abscesses, as opposed to incising the abscesses, was at first strongly opposed by the older surgeons.

As a diagnostician of tuberculous disease, Gauvain acquired a great and well-deserved reputation. In 1918, he first described the sign for the presence of active disease in the hip, which has since become known by his name, and his original description of which deserves repetition:

"If the femur on the affected side be grasped firmly in the region of the condyles, it will be found that the head of the bone may be gently rotated within the acetabulum, either inward or outward, through a varying but often considerable angle. When this movement is checked, but the disease remains active, a further slight sharp rotation is instantly followed by spasmodic muscular contraction, not confined to muscles about the joint but extending to the abdomen and visible in the abdominal muscles, or still more easily demonstrated if the palm of the hand is placed on the abdomen between the iliac spines. Quite a gentle and painless but sharp rotary movement is sufficient to provoke this reflex spasm of the abdominal muscles. Naturally, it would not be attempted where the disease is obviously active, but in just those cases where doubt exists I have found it a sign of the utmost value. With a little practice the sign is easily and safely obtained if the disease is active."

Although Gauvain's early reputation rests upon his crusade for the efficient conservative treatment of tuberculosis, in the widest sense, he was by no means opposed to surgical intervention at the appropriate time. Spine fusion, extra-articular arthrodesis of the hip, and other fixation and stabilizing procedures were practised, but it was always emphasized that these were procedures for the selected case, only to be carried out when the disease was quiescent as a mechanical means of acquiring stability in a part left unstable as the result of disease, and not procedures to be adopted in active disease or to shorten the period of essential conservative treatment.

A gifted speaker with a pleasing and lively manner, Gauvain found many an occasion to spread and emphasize his views, and although his style was perhaps more suited to the popular scientific lecture than to the studious paper, he always gained a ready hearing in both medical and lay audiences; and his manner was such that his addresses were remembered long afterwards. He delivered the Hastings Popular Lecture at the British Medical Association Annual Meetings of 1924 and 1933. In 1926, he went on a lecture tour in the United States of America and in Canada. In 1936, he received the Distinguished Service Gold Key of the American Congress of Physiotherapy. In 1935, he was President of the Tuberculosis and Public Health Section at the British Medical Association meeting held in Australia, and received the honorary degree of Doctor of Medicine from the University of Melbourne. Gauvain also held office as President of the Sections of Diseases of Children, Orthopaedics, and Electrotherapeutics of the Royal Society of Medicine of London.

Gauvain's interest in orthopaedic surgery was in no sense confined to tuberculous conditions, and in recent years he had become particularly interested in poliomyelitis. It had been planned to develop the Seaside Branch of the Treloar Hospital as a center for treatment of paralytic conditions on a large scale. In 1938, Gauvain visited the United States in order to study at first hand the Warm Springs Foundation and other centers where paralytic conditions are especially treated. Plans were again drawn up for a new extension of the work of the Treloar Hospital, and it was one of Gauvain's greatest disappointments that the War has prevented the development of this scheme to provide comprehensive treatment for a range of crippling conditions, for which adequate facilities are not yet available.

As a result of his interest in sunlight as a therapeutic agent, Gauvain became much interested in heliotherapy in all forms and in particular in the treatment of lupus vulgaris. This interest led to the establishment of a plastic unit, primarily for the treatment of scarring left by lupus, but now treating a large range of congenital and acquired defects amenable to plastic surgery.

No appreciation of Sir Henry Gauvain would be complete without some reference to the man himself.

A man of great personal charm, he was able to arouse affection and loyalty in his staff. He was also a man of action and great administrative ability. Always ready to listen, and to discuss suggestions and difficulties with his staff, once a decision was arrived at, it was adhered to and pursued unswervingly.

It was his pride that Treloar Hospital, in which his interest was so very personal, was a happy hospital, and this faculty for keeping his patients happy and contented was to him a very real and essential part of treatment. It was perhaps particularly exemplified by the way in which his essential kindliness and greatness of heart won the affection and secured the contentment of his child and adult patients at his private clinic at Morland Hall, Alton.

An apostle of conservatism in an era which has seen the greater part of the development and elaboration of orthopaedic operative technique, Gauvain's contribution to orthopaedic surgery is perhaps greater than is at present realized.

To those who knew him, he will long remain a friend and mentor whose wisdom, kindliness, and humor will not be forgotten.

PHOTOGRAPH BY BACHRACH

FRED H. ALBEE

1876–1945

In the death of Fred Houdlett Albee on February 15, 1945, in New York City, surgery has lost one of its most outstanding figures. Dr. Albee was known the country over and, at the time of his death, in all probability was one of the best-known orthopaedic surgeons in the world. Although he was the recipient of numerous honors at home and abroad, readers of *The Journal* will not require a list of his attainments. Other readers will find such a list in accurately factual obituaries published elsewhere.* The purpose here is more to recall the characteristics and interests of a friend long known, and to record the sense of loss which his death engenders.

Fred Albee's personality was an unusual one. Endowed with great energy, he never spared himself in devotion to his chosen field of orthopaedic surgery. He was one of those rare individuals who, as the years

*See *The Journal of the American Medical Association*, CXXVII, 477, February 24, 1945.

accumulate, never lose their youthful enthusiasm, but eagerly look for new things which will contribute to man's progress. Although, in a way, Dr. Albee was one of the crusading type, he was always kindly, courteous, and considerate of the opinions of others. He was a great traveler, and his familiar, sturdy figure will be missed at meetings of orthopaedic surgeons.

The founding of the International Society of Orthopaedic Surgery was without doubt due to Dr. Albee's efforts. He was president of many organizations during his career, including The American Orthopaedic Association and The International College of Surgeons.

Contributions to surgical literature made by Dr. Albee were far too numerous to record here, but his early works, "Bone Graft Surgery", published in 1915, and "Orthopaedic and Reconstructional Surgery", issued in 1919, were in their day outstanding. In 1937 appeared "Injuries and Diseases of the Hip", and in 1940 was published "Bone Graft Surgery in Disease, Injury, and Deformity", dedicated to the progress of bone and joint surgery. They are valuable contributions by a seasoned and experienced surgeon. No man contributed more original methods with reference to the use of bone grafts than did Dr. Albee; he was truly a pioneer in that field.

Dr. Albee's interest in the art and science of orthopaedic surgery resulted in his giving much time and energy to rehabilitation of the handicapped. He became particularly active in this work in the course of the War of 1917–1918, when he held the rank of Colonel and was Chief of Staff of General Hospital Number 3, situated at Colonia, New Jersey. It was due to his efforts that there was established, at Colonia, the first rehabilitation center, from which sprang the New Jersey Rehabilitation Commission. In 1940, for his twenty years' service as Chairman of this Commission, he was honored with a testimonial dinner, sponsored by the State Department of Labor and Rehabilitation.

Dr. Albee's family life was a most happy one. His devoted wife shared his many interests. A son, Fred, is just entering the practice of medicine. Closely interwoven with Dr. Albee's family life was the Medical Center at Venice, Florida, which was a project dear to his heart. He spent much time there, living on his estate, where his active interest in many phases of agriculture had free sway.

Some who read these paragraphs will be old friends of Fred Albee, some will be men of a younger group who were stimulated by his demonstrations and clinics, many will be acquainted with him only through the written word. All will join in tribute to a man who did much for surgery and especially for orthopaedic surgery. His efforts of a lifetime aided, and brought relief from pain to many patients.

BENJAMIN FRANKLIN BUZBY

1891–1944

Dr. Benjamin Franklin Buzby of Philadelphia died on October 22, 1944, at the age of fifty-three years. He held the positions of orthopaedic surgeon to the Germantown Hospital in Philadelphia, the Cooper Hospital in Camden, New Jersey, the Burlington County Hospital in Mount Holly, New Jersey, and of consulting orthopaedic surgeon to the New Jersey State Hospital for Tuberculosis at Lakeland.

He was born July 31, 1891, at Swedesboro, the son of Dr. Benjamin F. and Emma Holbrook Buzby. He received his degrees of Bachelor of Arts and Doctor of Medicine from the University of Pennsylvania in 1911 and 1914, respectively.

During the last War he served overseas as a Captain in the Army Medical Corps. He was President of the Camden County Medical Society during 1937–1938.

He was a member of The American Orthopaedic Association, and of The American Academy of Orthopaedic Surgeons, a Fellow of the American College of Surgeons and of the Philadelphia Academy of Surgery.

Dr. Buzby contributed many papers to orthopaedic literature, the one on the functional results of excision of the elbow being particularly noteworthy. He was a very hard worker with almost unlimited energy and enthusiasm. He was of very honest and upright character, was devoid of all petty meanness, and was respected and admired by his associates.

He was a member of the Philadelphia Racquet Club, the Philadelphia Country Club, the Camden City Club, and the Pine Valley Golf Club.

He is survived by his wife, Mabel, and by two children, a son, aged seventeen, and a daughter, aged nineteen, to all of whom he was particularly devoted.

News Notes

THE BRITISH ORTHOPAEDIC ASSOCIATION

The Annual Meeting of The British Orthopaedic Association was held in London, on December 15 and 16, 1944, under the presidency of Mr. St. J. D. Buxton. The principal subjects of discussion the first day were the vascularization of muscles, the denervation and re-innervation of voluntary muscles, and certain phases of war surgery.

In discussing vascularization of muscles, Professor W. E. Le Gros Clark said it is well known that most muscles are supplied by two or more main blood vessels, and injected specimens show clearly that their branches effect a number of anastomotic connections inside the muscle. But such material gives no real indication of the adequacy of these connections for the establishment of a collateral circulation; nor does it show whether interruption of one of the main vessels, or of one of their intramuscular branches, may lead to a localized ischaemia severe enough to be of practical importance. These problems have been studied in rabbits by the ligature of blood vessels supplying muscles, the results being assessed partly by subsequent histological examination, and partly by using a highly diffusible dye, bromophenol blue. This dye rapidly colors all normal muscles after intravenous injection, and is of particular value for assessing the physiological efficiency of the circulation, since it indicates the degree of interchange between the capillaries and muscle tissue, even when a feeble circulation in the main blood vessels may be still present. The efficiency of the anastomotic connections was found to vary considerably in different muscles. In some, such as the tibialis anterior, ligature of one of the vessels of supply leads to a sharply defined area of ischaemia. Two days after ligature of the lower vessel of supply to the tibialis anterior, intravenous injection of bromophenol blue stains the upper half of the muscle to a normal intensity, but the lower half remains almost entirely unstained, and the boundary between the two areas is sharply defined. The normal vascularization of the lower half of the muscle is not restored for about a week. If both of the main vessels supplying the tibialis anterior are ligatured, revascularization is delayed for two weeks. In experiments in which small steel ball bearings were shot through the adductor muscles of rabbits, at velocities of 250 to 1000 meters per second, localized and sharply defined areas of ischaemia were produced, as a result of interruption of the muscle vessels. Histological study of the unstained areas of muscle in these experiments showed that most of the muscle tissue had undergone necrosis. The necrotic tissue is removed quickly by the invasion of granulation tissue with abundant macrophages, and its removal is soon followed by the regeneration of new muscle fibers. The experiments show that in the muscles of the rabbit there is a remarkable potentiality for regeneration in devascularized tissue, and that, in spite of anastomotic connections, the interruption of one vessel of supply to a muscle, or of one of its branches, may lead to a relatively extensive and well defined area of ischaemia, lasting for several days. This is important in relation to the infection of muscles in war wounds.

Dr. Ruth Bowden demonstrated the importance of maintaining function in voluntary muscles, denervated as a result of peripheral-nerve injury. In such cases, atrophy is most rapid in the early stages of paralysis, when there is an increase of connective tissue, associated with wallerian degeneration in nerve fibers, and obliteration of the terminal Schwann tubes and motor end plates. Eventually, as muscle fibers continue to atrophy, they are replaced by fat and by connective tissue. Finally, the muscle may resemble tendon. Up to a year after denervation, a fair degree of functional recovery may be expected; nevertheless, the atrophy and replacement by connective tissue starts after three months. The reversibility of the changes in muscle depends upon such things as sepsis, age, mobility of the limb, and physiotherapy, as well as upon the nature of the lesion in the nerve itself. The electrical changes in denervated muscle are due, not so much to degeneration, as to atrophy. The more sluggish response to galvanic stimuli is due to the impulse being conducted through muscle, instead of through nerve. The response may disappear altogether, if atrophy is advanced. Electromyography reveals changes accompanying fibrillation, which persists as long as any denervated contractile fibers remain, and the special type of action potential noticed during the early stages of re-innervation. Dr. Bowden stressed the value of galvanism in maintaining muscle activity, and in limiting the degree of atrophy. It must be regular, and be started as soon as possible after injury. Contractures which may develop in denervated muscle, because of the connective-tissue formation, can be retarded by physiotherapy, and may be prevented by daily movements throughout the whole range of the joints of the limb. Splinting of paralyzed muscles should never maintain complete immobility.

Lieutenant Colonel E. A. MacNaughton, Royal Canadian Army Medical Corps, described the technique of early wound closure and treatment in plaster of ten compound fractures of the femur. Provided that the immediate primary treatment had been adequate,—excision of the wounds, and general treatment with blood transfusions, penicillin, or sulfonamides—the thigh wounds in these compound fractures were

completely closed, without drainage, a week or so later. Closure was accompanied by accurate reduction of the fracture, and, where required, stainless-steel wires or vitallium screws were used in its fixation, without interfering with wound healing. Colonel MacNaughton emphasized the importance of adequate preparation of the patients for operation by rest, replacement of blood loss, further penicillin before and after operation, and avoidance of examination of wounds in the wards before operation.

Lieutenant Colonel R. Zollinger, Medical Corps, Army of the United States, questioned the value of sulfonamide drugs inserted into wounds. This is unnecessary if the primary excision has been adequate. Sulfonamides thus inserted do not penetrate far into crevices, where it is often important to maintain a high concentration of the drugs; this could be ensured only by adequate general administration.

On the second day there was a discussion on amputations and limb-fitting at Queen Mary's Hospital, Roehampton.

Mr. F. G. St. Clair Strange read a paper on the "Amputation Stump, in Health and Disease". The amputation stump must be considered a new and normal organ, on the perfection of which will depend the health and happiness of the patient. It should be an evenly truncated cone, having the smoothness of skin and scar mobility which follows healing by first intention, and with no scarring or oedema in the subcutaneous tissues. The stump requires an internal scar, between the cut surfaces and the top surfaces of the flap; normal structure and function of the muscles inserting into the stump; rounding off of the bone end, with its covering layer of compact bone; and the special adaptation of function in the stump to control the artificial limb. The flaps should be rounded, and should contain deep fascia, in order to retain lymphatic, blood, and nerve supply to the skin. There must be minimal trauma of nerves. Bone and periosteum must be cut at the same level; and hemostasis and skin suture must be carefully done. Postoperative care should avoid the development of flexion contractures. Mr. Strange stressed the importance of minimal disturbance of dressings. Elastic bandaging of the stump should be used from the twelfth day, to shrink the stump without forming a "waist"; non-resisted exercises should be encouraged from the twelfth day, whereas progressive resisted exercises do not begin until three and a half weeks after amputation. Stumps are ready for measuring in four to six weeks, and are ready for the artificial limb by the time it is made.

Professor N. Priorov gave a résumé of the experiences with amputations in a large area under his control in Russia. Plaster was applied to the stumps to facilitate transit in cases of primary guillotine amputations in field hospitals. The first dressing was never done before the eighth day. Secondary suture of long skin flaps was often done with sutures inserted through plastic buttons, which can be pulled up gradually until closure is effected. The operative technique included muscle tamponade of the end of the bone canal. Temporary bucket peg-leg prostheses are extensively used.

Mr. George Perkins emphasized the importance of the deep fascia and its treatment in providing a mobile scar.

Colonel Stout, New Zealand Army Medical Corps, said that, in the New Zealand Army, all amputations were left open until the fourth or fifth day, and were then sutured; they were expected to heal by first intention.

Major Mather Cleveland, Medical Corps, Army of the United States, said that American Army surgeons were told to carry out circular amputations at the lowest possible level. In most cases, these were followed by skin traction within a plaster bucket. The soldier was then evacuated to the interior, where definitive treatment was carried out.

Professor T. P. McMurray asked surgeons not to be hasty in carrying out amputations; even a bad limb of his own might be more acceptable to a man than an artificial one.

Dr. A. J. Craft demonstrated all the standard limbs supplied by the Ministry of Pensions.

Mr. R. D. Langdale Kelham, in a paper on amputations in children, stressed the need for making stumps as long as possible, because the stumps of children do not grow as much as their normal limbs.

Colonel Rex Diveley, Medical Corps, Army of the United States, presented a moving picture film, dealing with the life of a man who had two arms amputated and yet attained a high degree of independence.

Major John Charnley, Royal Army Medical Corps, demonstrated an adjustable weight-bearing caliper splint, designed on the Thomas principle, but suitable for mass production in a variety of standard sizes, having a ring for ischial-bearing, which is adjustable within limits for different thigh circumferences, and upright irons adjustable for length by a screw-fitting extension. With a suitable supply of basic parts, fitting and supplying such an appliance took an hour or two, compared with the several weeks required for a product made to measure.

During the meeting honorary membership was conferred on Sir Alfred Webb-Johnson, President of the Royal College of Surgeons, and on Mr. J. Rhaiadr-Jones, Chairman of the Executive Committee of the Central Council for the Care of Cripples. Other new members elected were:

Full Members:

T. P. Kilner, F.R.C.S., London, W. 1.
A. H. McIndoe, F.R.C.S., London, W.1.
Rainsford Mowlem, F.R.C.S., London, W.1.

Associate Members:

Douglas Freebody, F.R.C.S.E., Putney, S.W.15.
W. Herschell, M.B., Ch.B., Stanmore, Middlesex.
Surg. Cdr. Claude Keating, R.N., Brisbane, Australia.
Flt. Lt. F. B. Kiernander, R.A.F., Oxford.
Surg. Lt. Cdr. R. A. Mogg, R.N.V.R., Cardiff, Wales.
Dr. W. W. Ollerhead, London, Ontario, Canada.
J. D. Raftery, F.R.C.S., New Barnet, Hertfordshire.
Squad. Ldr. W. T. Ross, R.A.F., London, W.2.
Christopher Rowlands, M.B., Ch.B., Llanrhaiadr, Oswestry.
Squad. Ldr. T. B. Russell, R.A.F., Thornton Hall, Lanarkshire.
S. Smith, M.B., Ch.B., Glasgow, Scotland.
Squad. Ldr. E. Somerville, R.A.F., Halton, Wendover, Buckinghamshire.
Flt. Lt. R. A. Trevethick, R.A.F., Sheffield, 11.
Surg. Lt. J. Wishart, R.N.V.R., Glasgow, N.W., Scotland.

In the January issue of *The Journal* was given a list of Fellows of **The American Academy of Orthopaedic Surgeons,** elected during the year 1944. The name of Martin Batts, Jr., should have been included. Dr. Batts was elected to Fellowship, but died on July 8, before he received his diploma which has been awarded posthumously.

The Fifty-Ninth Annual Meeting of **The American Orthopaedic Association,** planned for May 28 to 31, at The Homestead, Hot Springs, Virginia, has been cancelled at the request of the Office of Defense Transportation.

ACKNOWLEDGMENTS

The Journal wishes to acknowledge the receipt of the following publications sent to the Editorial Department:

Anais Paulistas de Medicina e Cirurgia (São Paulo, Brasil), XLVII, No. 6; XLVIII, Nos. 1, 2, e 5, 1944.
Analecta Medica (Mexico), V, Nos. 3 y 4, 1944.
Boletim do Sanatório São Lucas (São Paulo, Brasil), V, No. 12; VI, Nos. 1, 2, e 5, 1944.
Boletin del Colegio Médico de la Habana (Cuba), VII, Núms. 9, 10, y 12, 1944; VIII, Núm. 1, 1945.
Boletines de la Sociedad de Cirugía de Rosario (Argentina), XI, Nos. 3, 4, y 7, 1944.
Boletines y Trabajos de la Sociedad de Cirugía de Córdoba (Argentina), V, Nos. 4 y 5, 1944.
The Bulletin of the U. S. Army Medical Department (Carlisle Barracks, Pennsylvania), Nos. 81, 82, and 83, 1944; Nos. 84, 85, and 86, 1945.
The University of Chicago Announcements. The School of Medicine, Sessions of 1944–1945. XLIV, No. 13, 1944.
Child Development Abstracts and Bibliography (Washington, D. C.), XVIII, Nos. 3 and 4, 1944.
Cleveland Clinic Quarterly (Ohio), XI, No. 4, 1944; XII, No. 1, 1945.
Current Medicine (Los Angeles, California), XII, No. 1, 1945.
Harper Hospital Bulletin (Detroit, Michigan), II, No. 3, 1944.
The Johns Hopkins University Circular, School of Hygiene and Public Health, Catalogue Number, 1944–1945. Baltimore, The Johns Hopkins University, 1944.
Médica (Matanzas, Cuba), III, Núms. 4, 5, y 6, 1944.
National Foundation for Infantile Paralysis, Inc. (New York, N. Y.), Annual Report, 1944; Miracle of Hickory, Publication No. 53, 1944.
National Foundation News (New York, N. Y.), IV, No. 2, 1944; Nos. 4 and 5, 1945.
National Society for Crippled Children of the U. S. A., Inc., Annual Report, 1944.
El Nuevo Hospital (La Habana, Cuba), III, Núms. 1–10, 1944.
The Physiotherapy Review (Chicago, Illinois), XXIV, No. 6, 1944; XXV, No. 1, 1945.
Radiography and Clinical Photography (Rochester, New York), XX, No. 2, 1944.
Revista Cubana de Obstetricia y Ginecología (La Habana, Cuba), VII, Nos. 1 y 2, 1945.
Sanidad y Beneficencia Municipal (La Habana, Cuba), III, Núm. 4, 1944; IV, Núm. 1, 1944.
War and Postwar Rehabilitation and Reconditioning, The Baruch Committee on Physical Medicine, 1944.

Current Literature

SHOULDER LESIONS. H. F. Moseley, M.A., D.M., M.Ch. (Oxon.), F.R.C.S. (Eng. and C.), F.A.C.S. Springfield, Illinois, Charles C. Thomas, 1945. $4.50.

The expressed purpose of this book is to make available to the reader a short up-to-date account of current knowledge pertaining to certain painful lesions of the shoulder. This purpose is carried out in an orderly and readable fashion so that the busy practitioner will encounter a minimum of difficulty in obtaining a comprehension of the basic pathology, differential diagnosis, and accepted forms of therapy for the various forms of painful shoulder so often encountered.

An introductory chapter deals with normal anatomy and physiology; and the relative importance and interdependence of the various units of the "arm trunk mechanism" are emphasized and illustrated by clinical examples. Following a description and discussion of the general points of clinical examination, the detailed points of examination, along with the basic pathology and various forms of therapy, are discussed in successive chapters dealing with cuff tears, subluxations and dislocations, calcific deposits, the bicipital syndromes, and periarthritis with its allied conditions. Dr. F. L. McNaughton contributes an excellent chapter, which in twenty-two pages covers the neurological aspects of shoulder pain in a comprehensive manner; and Dr. Jean Bouchard and Dr. C. B. Peirce a chapter of twenty-six pages covering x-ray examination and therapy. The commoner operations are described and supported by case reports. Proper emphasis is laid on re-education of function in a separate chapter, which in its detailed discussion of rehabilitation procedures will be of great value to the reader.

The only major adverse criticism possible is that the discussion of fractures is confined to less than four pages. The common bone injuries of the shoulder girdle would seem to be worthy of a more important place than has been allotted them.

The work is well illustrated and accompanied by an excellent bibliography. It will constitute a valuable manual of shoulder lesions for the general practitioner.

QUISTES SIMPLES DE LOS HUESOS (SIMPLE BONE CYSTS). Oscar R. Maróttoli. Buenos Aires, El Ateneo, 1943.

This is an excellent monograph on the subject of simple bone cysts. It comprises 220 pages, and includes about 240 figures, most of them preoperative and postoperative x-ray studies of the author's cases. It is well presented, written in simple, clear, and straightforward style, and is a thorough exposition of the subject. It can be read rapidly and with interest, and is so well organized that one can readily use it as a reference to obtain the outstanding opinions on experimental, pathological, and clinical aspects of simple bone cysts.

The chapters on pathogenesis and gross and microscopic pathology are especially good, and numerous illustrations accompany the text. The experimental studies made by the author are discussed, but not elaborated upon to the exclusion of the clinical side. The chapters on roentgenographic signs, and the differential diagnosis of bone cysts from dystrophy, inflammatory and metabolic lesions, and tumors are carefully presented.

With this material for a background, the operative and postoperative methods of treatment are discussed, and the results recorded with particular emphasis on the author's cases. An honest effort has been made to solve this therapeutic problem to the best of our present knowledge.

This is a valuable monograph.

THE 1944 YEAR BOOK OF INDUSTRIAL AND ORTHOPEDIC SURGERY. Charles F. Painter, M.D., Editor. Chicago, The Year Book Publishers, Incorporated, 1945. $3.00.

The reader of a year book wishes to be introduced to the most important contributions on the subject to the medical literature of the year. The actual value of such a book depends, therefore, upon the care and good judgment with which the articles reported have been selected.

The 1944 Year Book of Industrial and Orthopedic Surgery, as its predecessors, is a review of the best contributions to these fields during the past year. In the section on Orthopedic Surgery, certain subjects seem to have received special emphasis in the literature. For instance, there have been many valuable articles on lesions of the shoulder, and the better understanding of dislocated and herniated intervertebral discs has led many authors to write upon these conditions, their causes, and their place in differential diagnoses. Surgeons in the Armed Services have offered for publication reports of unusual cases and studies of the more common injuries of the locomotor system. Conditions seldom seen in private practice have been observed very frequently in Army personnel.

Part II is devoted to Industrial Medicine and Surgery, and the articles to which reference is made deal with the general problems of health in industry, as well as the unusual conditions and hazards of wartime, and the specific problems of occupational diseases.

This Year Book meets a real need, and is an excellent compilation of the important contributions in this field during the past year.

MODERN METHODS OF AMPUTATION. Edmundo Vasconcelos. (With an Introductory Survey of the Development of Amputations by Major General Norman T. Kirk, M.C., Surgeon General of the United States Army.) New York, The Philosophical Library of New York, Department of War Medicine, 1945. $10.00.

The text, which pertains to the timely subject of amputations, opens with an Introductory Survey on the Development of Amputation by Major General Norman T. Kirk, whose contributions to this subject are well known. This Survey is reprinted in its entirety from an article appearing in the *Bulletin of the Medical Library Association*, April 1944. It is written in an interesting and scholarly manner, indicative of extensive historical research, and is a valuable contribution to the history of amputations, particularly as related to war. There are several excellent illustrations of historical interest, which have been reproduced from ancient and mediaeval writings.

The first three chapters deal with general considerations, including indications for amputation, sites of election, and preoperative and postoperative treatment. These subjects are well covered by the author, who is Professor in the University of São Paulo. In the main, his ideas are in agreement with those widely accepted. The influence of surgical writings from continental Europe is apparent. Some of this latter material is not altogether in accord with practice in the United States and Great Britain.

Chapters IV and V contain detailed descriptions of the technique of individual amputations, and they are thorough and comprehensive. Considerable space is devoted to a description of complicated amputations through the tarsal bones, many of which are not accepted in this country. Where satisfactory prostheses are not readily available, such operations may be useful, but where the art of limb making is highly developed, amputations of this type are not recommended. Amputations at a higher level are more easily performed, and most surgeons consider them more satisfactory.

The greatest value of the book lies in its well-executed pen drawings, which illustrate with great clarity the various steps in operative technique. The text is not well arranged, and the translation is poor, revealing a surprising lack of familiarity with English medical terms. The result is awkward and rather stilted, and it is difficult to determine the author's exact meaning in many parts of the text.

AIDS TO ORTHOPAEDIC SURGERY AND FRACTURES. I. E. Zieve, M.A. (Capetown), F.R.C.S. (Eng.). Ed. 2. London, Baillière, Tindall and Cox; Baltimore, The Williams and Wilkins Company; 1944. $1.75.

This is a second edition of a small book of 260 odd pages. It is really a glorified dictionary of orthopaedic surgery, and covers practically everything in a superficial, but most intelligent way. It contains very little operative description of anything, except in general terms. There is no bibliography and there are no illustrations. The treatments, including the surgical treatments of all the various conditions described, are most conservative. Certain standardized and well-recognized methods of treatment and operation are advocated, rather than any discussion of operative procedures which might be employed for each type of case or condition. This, of course, leaves the uninitiated surgeon with but one choice.

As one reads it, in places, it seems a little bit old-fashioned, and some of the British terms are not in common usage in this country. On the whole, it is a very interesting and useful book, and certainly reduces things to first principles. The subject matter is very clearly presented in eight chapters and is well grouped,—fractures, congenital deformities, acquired deformities, and so forth. For the physician in general practice, and even for an orthopaedic surgeon, it is a very useful, small book to own.

A LIST OF BOOKS AND PAMPHLETS ON THE HISTORY OF SURGERY AND ORTHOPEDIC SURGERY. In the Collection of Dr. H. Winnett Orr, Lincoln, Nebraska. Ed. 2. Lincoln, Jacob North & Co., 1945.

This is a catalogue of his own library, compiled by Dr. Orr. Included with the books, many of which are old and rare, are the twelve scrap books which Dr. Orr has built over the years. Five of these reveal the development of the Orr method of treatment of compound fractures and osteomyelitis; another, the experiences of the American Orthopaedic Unit in World War I; and others, memorabilia of The International Orthopaedic Society, The Nebraska Orthopaedic Hospital, and The American Orthopaedic Association. The remainder are devoted to the history of surgery and of orthopaedic surgery, to Lord Lister, and to Dr. Orr's own private and professional life.

Dr. Orr's books constitute one of the finest private surgical libraries in America. The mere list of titles is a delight to the bibliophile. To the student of the history of surgery and the development of the older and the modern orthopaedic surgery, this library is an important source.

PHYSICAL TREATMENT OF ANTERIOR POLIOMYELITIS. Diana B. Kidd, C.S.M.M.G. London, Faber and Faber Ltd., 1943. 6 shillings.

In the introduction to this book, Maude Forrester-Brown, a well-known Scottish orthopaedic surgeon, is quoted as saying that three qualifications are necessary for a physiotherapist when treating patients with anterior poliomyelitis: an accurate knowledge of anatomy, great patience, and a gift of arousing the patient's cooperation.

The author stresses these qualifications in the text. Treatment is divided into the acute, the convalescing, and the chronic stages, and specific treatment is described for each phase of the disease. Attention is paid to general health conditions, and to the maintenance of improved circulation by means of massage and joint movements. A system for recording improvement of muscles is included. The author cites the advantages of the suspension-sling type of re-educational therapy over pool therapy. However, children usually respond readily to underwater exercises and enjoy themselves thoroughly. It is a great uplift to youngsters, who have some physical handicap, to feel that they are able to excel in any type of physical effort.

The suspension-sling exercises, with additional pulley weights which provide graded resistance for specific muscle groups, are explained, and pictures demonstrating the framework and the positions of the joints to be re-educated accompany the text.

A discussion of the possibilities of electrical stimulation and occupational therapy completes this practical handy textbook, which is to be recommended to students, and those practising physiotherapy in anterior poliomyelitis conditions.

THE ART OF RESUSCITATION. Paluel J. Flagg, M.D. New York, Reinhold Publishing Corporation, 1944. $5.00.

In the preface, the author states that his purpose is "to tell the reader what to do when faced with an acutely asphyxiated patient about to die". The first three sections, covering the first quarter of the volume, define the problem from a physiological and medical standpoint, and discuss the indications and methods for treatment. The various causes of asphyxia, such as poisoning from gases, submersion, electrocution, and respiratory obstruction are next described at length, and particular instructions are given for dealing with the different situations. Dr. Flagg suggests the organization of the teaching and administration of gas therapy including anaesthesia as a specialty, to be referred to as "pneumatology."

This book contains a mass of valuable material. The sections on methods of resuscitation and on transportation of the unconscious patient are particularly useful. The verbose and overdramatic style detracts from so serious a book. In spite of this criticism, "The Art of Resuscitation" is undoubtedly a useful book.

TODESFALL AN FETT-KNOCHENMARKEMBOLIE UND URÄMIE NACH "INTRADURALER" PER-ABRODIL-MYELOGRAPHIE (A CASE OF DEATH FROM FAT EMBOLISM AND URAEMIA FOLLOWING INTRADURAL PERABRODIL MYELOGRAPHY). A. Karlén. *Acta Chirurgica Scandinavica*, LXXXVII, 497, 1942.

A case is reported in which epidural myelography with twenty cubic centimeters of 35 per cent. perabrodil terminated fatally. An attempt was made to inject the material through the sacral hiatus so that it remained epidural in the diagnosis of protruded intervertebral disc. In spite of great care the fluid was deposited intradurally. In three-quarters of an hour the patient began to have back pain and cramps. His back muscles became spastic and boardlike. He became blue and cyanotic with cold perspiration. Three hours after the injection, he became unconscious. Three days later, the patient died, apparently because of uraemia, complicated by a fat embolism from the severe convulsions.

The writer could find no report of a similar case of death from attempted perabrodil epidural myelography. He did find nineteen fatal cases after the use of the same drug in pyelograms. Perabrodil is 49.8 per cent. iodine.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

OSTEOPLASTISCHE VERANKERUNG VON METALLPROTHESEN BEI PSEUDARTHROSE UND BEI ARTHROPLASTIK (OSTEOPLASTIC IMPLANTATION OF METAL PROSTHESES IN PSEUDO-ARTHROSIS AND IN ARTHROPLASTY). I. Boerema and J. de Waard. *Acta Chirurgica Scandinavica*, LXXXVII, 511, 1942.

Two cases in the human, and several in dogs are reported, in which stainless steel was implanted to bridge bone defects. In one case a fenestrated tube of bone was implanted in an ununited humerus. The function was good after one year.

In the second case a stainless-steel elbow joint was used to bridge a defect. One arm of the prosthesis was firmly driven into the humerus. The other was made fast to the ulna with some difficulty. At the end of fourteen months, there was 20 degrees of motion,—from 80 to 100 degrees.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

DENNA FESTSKRIFT TILLÄGNAS PROFESSORN I ORTOPEDI VID KUNGL. Karolinska Mediko-Kirurgiska Institutet, Henning Waldenström. (Memorial Volume.) *Acta Chirurgica Scandinavica*, LXXXVII, Numbers 2, 3, 4, 1942.

Numbers two, three, and four of Volume LXXXVII of the *Acta Chirurgica Scandinavica* appeared as a memorial book dedicated to Professor Henning Waldenström on his sixty-fifth anniversary, August 14, 1942. Twenty-eight students and friends contributed a variety of brief articles of orthopaedic interest. Stereoscopic photography, the erroneous diagnosis of sarcoma, the epidural injection of abrodil in the diagnosis of disc protrusion, urinary calculi in hyperparathyroidism, ossifying hematoma, bone grafting in the treatment of recurrent dislocation of the shoulder, and the etiology of coxa plana are some of the varied subjects.

Probably because of the War, the contributors were limited to the Scandinavian countries, and principally Sweden. Soon after the publication of this volume, Professor Waldenström retired as Professor of Orthopaedics at the Karolinska Institutet. His place was taken by Sten Friberg.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

DER EINFLUSS ÖRTLICHER NOVOCAININJEKTIONEN AUF DIE FRAKTURHEILUNG (THE INFLUENCE OF LOCAL NOVOCAINE INJECTION ON FRACTURE HEALING. AN EXPERIMENTAL STUDY). Einar Bohm and Gosta Flyger. *Acta Chirurgica Scandinavica*, LXXXIX, 97, 1943.

There is a growing tendency to treat certain linear fractures by repeated novocaine injection without immobilization. There are numerous reports in the literature of cases where such treatment has produced more rapid healing with less disability. To investigate this method, the writers broke the right fibula just above the malleolus in a series of rats. The fractures were produced with little or no displacement. Two-tenths of a cubic centimeter of a sterile 1 per cent. novocaine solution was injected directly into the site of this fracture. For the first week the injection was carried out daily; during the second week, every second day; and during the third week, every third day. Roentgenograms were taken and the rats sacrificed at various stages of healing from the third to the twenty-fifth day.

On the basis of their studies, the authors conclude that:

1. Hyperaemia sets in sooner in the case of the animals treated with novocaine than in those not treated. Maximum hyperaemia was reached in ten days in the treated animals, but not for twenty-five days in the untreated. After twenty-five days in the treated fractures, the vascular condition about the fracture had returned to normal.

2. Healing appeared to proceed more rapidly following injection of novocaine. After twenty-five days in the treated cases, complete reorganization of the callus occurred. After twenty-five days the control cases still had spongy callus which even contained connective tissue. Only one of seven of these cases exhibited any reorganization. Convincing illustrative sections at six, ten, fourteen, and twenty-five days are submitted.—*Walter P. Blount, M.D., Milwaukee, Wisconsin.*

SYNOVIAL SARCOMA. Cushman D. Haagensen and Arthur Purdy Stout. *Annals of Surgery*, CXX, 826, 1944.

SYNOVIAL SARCOMA AND NORMAL SYNOVIAL TISSUE CULTIVATED *in Vitro*. M. R. Murray, Arthur Purdy Stout, and I. A. Pogogeff. *Annals of Surgery*, CXX, 843, 1944.

These articles are combined for review because the laboratory studies were undertaken to obtain confirmation of the mesothelial nature of synovial sarcoma by tissue culture in three cases. An investigation of the subject seemed necessary because many reports on this rare form of tumor were disappointing, since a considerable number of the cases were, in reality, xanthomatous giant-cell tumors, tumor-like hyperplasias of synovial tissue, or other benign lesions curable by excision.

The tissue from three cases of human synovial sarcoma was cultivated *in vitro* and was compared with similarly treated normal synovial tissue from the knee joint of the adult rat. The normal synovial cell appears to be a specific type of cell distinct from other epithelium and from the fibroblast. But the synovial sarcoma appears to be a distinct type of neoplasm exhibiting certain similarities to the mesothelioma.

The three tumors had definite histological characteristics. They were composed of an inextricable admixture of mesothelial cells, with strands of active hyperchromatic cells resembling fibrosarcoma, associated with reticulin fibers. It was decided to regard these as the characteristic features of such tumors. On this basis, the previously reported cases were re-examined, and those which failed to satisfy the criteria were rejected. This screening yielded ninety-five cases; to these were added nine new cases which are reported in detail.

The synovial sarcoma is a highly specialized and rare form of neoplasm which attacks the extremities. It develops slowly, is more common in young adult males, and metastasizes through the blood stream or occasionally to the regional lymph nodes. The diagnosis should be established by histological examination of material obtained through a small non-traumatizing incision. Treatment is by high amputation and perhaps regional lymph node dissection. Roentgenotherapy is ineffective.

Of the entire group of 104 cases studied by the authors, only three are known to be free of metastases more than five years after treatment.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

War Surgery in Africa. W. H. Ogilvie. *The British Journal of Surgery*, XXXI, 313, 1944.

The lot of the wounded man in this war is better than that of his father. His suffering has been minimized and his chances of useful survival are greater. The soldier of today is a more physically-fit man, and he fights under better conditions. The chances of relief of hemorrhage and shock by blood and plasma are better and the sulfonamides have reduced the dangers from infection. Methods of immobilization are better and so are the methods of transport.

It is impossible to reduce the surgery of modern warfare to a system. Each military enterprise is a fresh surgical problem. Local factors—such as the time-lag in reception, the equipment of the unit, and the conditions of evacuation—will modify any set of general principles which are laid down.

First-class surgery can be done under very simple conditions, provided the wounded man can be placed in the care of competent surgeons without delay.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

Studies in the Pathology of Human "Immersion Foot". W. Blackwood. *The British Journal of Surgery*, XXXI, 329, 1944.

Pathological material from fourteen cases of immersion foot has been studied. The article is illustrated by many photographs (some in color) and photomicrographs.

"A histological study of tissues from cases of immersion foot showed that damage was done to all tissues in the extremity. Blood vessels, muscles, nerve trunks, and bone were particularly examined. The relative severity of injury to the tissues varied, being most severe in nerves and muscles. Material from early survivors was not available, but it is likely that the early histological reactions are similar to those seen in the experimental animal. There was evidence of restoration towards or to normal of tissues which had not been killed by the initial trauma. Nerve regeneration occurred and, though slow, did not appear to be grossly so; and denervated muscle returned to normal, provided that the delay was not so long that irreversible degeneration and fibrosis had ensued."—*Ernest M. Daland, M.D., Boston, Massachusetts.*

Observations on the Regeneration of the Semilunar Cartilages in Man. I. S. Smillie. *The British Journal of Surgery*, XXXI, 398, 1944.

Fourteen patients were submitted to a secondary operation after all or part of the semilunar cartilage had been removed. It was found that where the whole cartilage had been removed a new one of about the same shape and appearance had formed, but it was composed entirely of fibrous tissue. Replacement also occurred after partial removal of the meniscus, but the attachment of the new tissue to the old was a weak one, and the replacement was probably not as good as a total replacement.

In five cases, injury was found in the replaced cartilage, but in every case it was found that there had also been previous injury to the cruciate or collateral ligaments, with a resulting unstable knee joint subjecting the new meniscus to undue strain.—*Ernest M. Daland, M.D., Boston, Massachusetts.*

El Procedimiento de Quesada en el Tratamiento de las fracturas diafisarias, irreductibles por tratamientos incruentos (Quesada's Method of Treatment of Diaphyseal Fractures, Irreducible by Closed Methods). Salvador de Lara. *Cirugía y Cirujanos*, XII, 179, 1944.

A description of the apparatus of Prof. Quesada is given by de Lara. This apparatus is used for the treatment of irreducible fractures of the shafts of the long bones. It consists of a plaster cast with an open metal frame over the area of the fracture. The usual methods of manipulation under anaesthesia and of traction are employed. If these are unsuccessful, open reduction is carried out through the open part of the Quesada apparatus. No internal fixation of the bones is used. The periosteum is carefully sutured. De Lara is opposed to the use of internal metallic fixation, because he believes that it produces trophic changes, delays healing, interferes with local circulation, and sometimes causes infection. The method of Quesada disturbs the physiology of the healing bone very little. Secondary displacements of the fragments are rarely seen with this method. The indications for this procedure are given as follows:

1. When it is not possible to obtain bloodless reduction manually;
2. When reduction cannot be maintained, because of deficient contact of the fragments;
3. When the fragments show jagged edges or teeth which prevent proper contact in the transverse plane;
4. When there is interposition of the soft parts;
5. When bone-grafting seems necessary;
6. In compound fractures.

The technique consists of immobilization in the Quesada apparatus for six to twelve days. Reduction is then carried out through the window of the apparatus. The periosteum is sutured and the soft parts are repaired. Traction is applied, when necessary to prevent bowing. Surgical intervention is thus carried out after any hemorrhage has been absorbed. Occasionally catgut or kangaroo tendon is required in oblique fractures. Sometimes in transverse fractures, one or two teeth are made in the ends to maintain reduction. The plaster is usually removed about nine days after the operation, and the limb is put in a protective plaster until the fracture is solid.—*John G. Kuhns, M.D., Boston, Massachusetts.*

El Método Fenestrado para el Enclavijamiento de las Fracturas del Cuello del Fémur (The Fenestration Method of Nailing Fractures of the Femoral Neck). Eduardo Alcívar Elizalde. *El Día Médico*, XVI, 554, 1944.

Fractures of the femoral neck may be divided into three classes:

1. Cervicotrochanteric,
2. Transcervical,
3. Subcapital.

The method of Whitman gives excellent results in the treatment of fractures of the first group. It has markedly improved the results in the other classes by reducing the number of pseudarthroses. To minimize this tendency toward pseudarthrosis Lambotte suggested, and Delbet subsequently modified, the method of holding the cervical fragments together with a screw. Subsequently Smith-Petersen recommended the use of the flanged nail, instead of the screw. It is this method which the author employs.

However, he notes that nailing, whether by the open method or the closed, necessitates trained personnel and specialized equipment which is not always available. To offset this difficulty, the author recommends a combination method which he calls the fenestration method.

The first part of the procedure consists in reduction of the fracture and immobilization in a Whitman plaster. A roentgenogram is then made. If the reduction is deemed satisfactory, a window thirty by fifteen centimeters is cut in the cast, and a Smith-Petersen nail is inserted over a Kirschner-wire guide. At the end of two weeks, the cast is shortened, so as to permit greater motion in bed. A month and a half after operation, the long plaster is removed, a short spica is applied, and the patient is permitted to walk about with the aid of crutches. At the end of three months, the patient walks without plaster, but with the aid of a cane. At the end of five months, the nail may be removed, if the roentgenogram shows bony trabeculation across the site of fracture.—*Henry Milch, M.D., New York, N. Y.*

Compression of Seventh Cervical Nerve Root by Herniation of an Intervertebral Disk. Paul C. Bucy and Harvey Chenault. *The Journal of the American Medical Association*, CXXVI, 26, 1944.

The authors have reviewed the literature on herniated intervertebral discs. They report in detail a case with paraesthesia in the thumb, index and middle fingers of the right hand, which extended up the radial aspect of the forearm; with mild weakness in the right triceps but without difference in the triceps reflex; without motor weakness in the right hand, but with hypalgesia, hypaesthesia, and hypothermesia over the right thumb and index and middle fingers, and on the radial border of the forearm. A diagnosis of herniated disc between the sixth and seventh cervical vertebrae compressing the right seventh cervical nerve root was made, and was confirmed at operation. Removal of the herniated portion resulted in relief of the symptoms. — *Joseph H. Reno, M.D., Dallas, Texas.*

Fracture of the Base of the Thumb. A New Method of Fixation. Eric C. Johnson. *The Journal of the American Medical Association*, CXXVI, 27, 1944.

The author reports two cases of Bennett's fracture of the base of the first metacarpal, in which fixation of the fragments was carried out, after manual reduction, by Kirschner wires and a plaster cast. The wires were passed through the thumb and second metacarpal after reduction by traction; a cast was then applied. Such immobilization for six to eight weeks yielded an excellent result in each case. — *Brandon Carrell, M.D., Dallas, Texas.*

Hemorrhagic Complications, with Death Probably from Salicylate Therapy. C. T. Ashworth and J. F. McKemie. *The Journal of the American Medical Association*, CXXVI, 806, 1944.

Two case reports of patients receiving salicylate therapy are presented,—one, a woman, twenty years of age, who received 150 grains of sodium salicylate daily for seven days; the other, a boy, four months old, who received fifteen grains of acetylsalicylic acid in two days. In both cases, hyperpnea, hyperpyrexia, and convulsions preceded coma, followed by death. The outstanding findings at autopsy were: hemorrhagic changes, widespread over the whole body but particularly involving the brain, and severe widespread hyperaemia. The explanation of these findings is probably a combination of capillary damage and hypoprothrombinaemia produced by the salicylates. The literature upon such effects by salicylates is reviewed. Vitamin K is urged as supplemental therapy when large doses of salicylates are used.—*J. H. Reno, M.D., Dallas, Texas.*

The Effect of Penicillin on Rheumatoid Arthritis. Edward W. Boland, Nathan E. Headley, and Philip S. Hench. *The Journal of the American Medical Association*, CXXVI, 820, 1944.

Large doses of penicillin were given to ten soldiers, with proved early and progressive rheumatoid arthritis, who did not have irreversible changes (destruction of cartilage and subchondral bone, or notable flexion deformities). The dosage of penicillin, given intramuscularly, was from 120,000 to 320,000 units daily for

from fourteen to twenty days. There was no definite improvement as measured by laboratory tests. There was no significant improvement in the sedimentation rates or in the comparative leukocyte counts on synovial fluid, made before and after treatment. In seven of the ten cases, there was no significant subjective or objective improvement. One patient felt worse, but objectively was unchanged. Another felt better, but there was no definite objective improvement. The remaining patient had moderate subjective and objective improvement in some of the affected joints; the sedimentation rate increased slightly during treatment, but he was neither cured nor decidedly improved. The authors decided that their results offered no support to the idea that hemolytic streptococci are etiologically related to the disease; that it is not caused by any of the bacteria which are already known to be rapidly affected by penicillin; and that penicillin trials in treatment of rheumatoid arthritis should be deferred until the drug becomes much more plentiful.—*H. H. Beckering, M.D., Dallas, Texas.*

COMPRESSION FRACTURE RESULTING FROM ACCIDENTAL STIMULATION OF CAROTID SINUS. Charles U. Hauser. *The Journal of the American Medical Association*, CXXVI, 1029, 1944.

During the application of a forearm cast, while seated upon a stool, a patient fainted and his head slumped forward against his moderately tight neck band. A strong convulsion immediately gripped him, causing his back to flex sharply with all his flexors tightening in a tetanic spasm for a few seconds. He was then laid upon an examining table where he remained unconscious for the next five minutes. Subsequent roentgenograms of the spine revealed compression fractures of the eleventh and twelfth thoracic vertebrae, resulting in about 25 per cent. reduction in the width of the anterior portion of the bodies.

Several factors contributed to the convulsion. The right carotid sinus was found to be hyperirritable. The normal, fasting blood sugar level was 93 milligrams. Fatigue from several sleepless nights, apprehension over a flexion strain of the wrist, pain in the wrist, and the usual hospital aroma, added to the low glucose level, helped to lower the threshold for stimulation of the normally hypersensitive carotid sinus.

Although convulsions from stimulation of a hyperirritable carotid sinus are rare, this case serves to point out the importance of treating a patient in a horizontal position. This should interest those surgeons who may use compression of the neck in various diagnostic manoeuvres.—*D. K. Barnes, M.D., Dallas, Texas.*

GROWTH ARRESTS FOR EQUALIZING LEG LENGTHS. J. Warren White and Sam G. Stubbins, Jr. *The Journal of the American Medical Association*, CXXVI, 1146, 1944.

The authors present this paper to popularize a simple surgical procedure which they have found to be of great value in solving the problem when in children one leg is enough shorter than the other to produce immediate or probable future disability. The White method of epiphyseodiaphyseal fusion is presented in detail, and those interested in a review of this should consult the original article. The differences from the better known Phemister method are pointed out. This is, in effect, a ten-year report of the White method. A useful method of graphically recording the discrepancy in the length of the lower extremities is presented which is very feasible, and this article should be studied for the details. Growth in the lower extremities of boys is stated to cease at seventeen years of age and in girls one year earlier. White feels that growth arrest of the distal femoral epiphysis would retard the growth of that extremity at the rate of three-eighths of an inch per year; at the proximal end of the tibia and fibula the rate of retardation is a quarter of an inch. These figures for calculations have not been faulty in ten years' experience with 149 cases.

The operation should be performed largely on those children in whom, at the age of ten or twelve, there exists upward of two inches of shortening.

In the discussion of this paper, Dr. Hatcher points out that girls do not mature as regularly as boys do, and that they mature earlier. In general, epiphyseal arrests have no value in the female if menstruation has started, because after that time the girl will grow no more from the lower extremities; she will increase slightly in height from growth of the spine.—*J. H. Reno, M.D., Dallas, Texas.*

NERVE LIGATURE FOR PREVENTION OF AMPUTATION NEUROMA. M. A. Egorov. *Khirurgiya*, No. 4, 38, 1944.

The prevention of neuromata in amputation stumps is still a problem. The known methods are not entirely satisfactory. The author had occasion to observe satisfactory results obtained by one of his former assistants, who used a massive ligature applied to the neurovascular stump. Following this method, the author ligated the nerves in the amputation stumps of twenty-seven children. He also cites a similar procedure in three amputations on adults. He emphasizes the comparative absence of phantom pain in the immediate postoperative period. Experimental ligations of the nerves were performed on fourteen dogs, and postoperative neuromata did not develop.

The author recommends the use of silk ligatures, applied tightly and separately to each severed nerve.—*E. Kaplan, M.D., New York, N. Y.*

GUNSHOT WOUNDS OF THE JOINTS. *Khirurgiya*, No. 1, pages 2–82, 1944.

This is a general review of the entire subject. The issue is of special interest because it contains thirteen articles on gunshot wounds of the joints, and their management at the forward battlefront area, in base hos-

pitals, and in the rear. It encompasses experience from a large number of cases. The predominating opinion of most of the authors is that gunshot wounds of joints, especially of the hip joint, require early radical operations, including resections and even disarticulations.

The following is a list of articles in the issue:

On Gunshot Wounds of Articulations and Their Treatment ..... V. S. Levit
Pathological Anatomy of Gunshot Wounds of the Knee Joint ..... P. P. Dvijkos
The Treatment of Gunshot Wounds of Large Joints ..... E. K. Molodaya
On Joint Resections Following Gunshot Wounds, Based on Cases from Evacuation Hospitals of the Deep Rear ..... A. T. Lidsky
Gunshot Wounds of the Elbow Joint ..... A. I. Makhotina
On the Problem of Gunshot Coxitis ..... M. O. Fridland
Gunshot Wounds of the Hip Joint ..... T. S. Zatsepin
Hip Disarticulation in Gunshot Wounds of the Lower Extremity ..... N. I. Makhov
Gunshot Wounds of the Hip Joint and Their Treatment ..... V. A. Chernavsky
On the Problem of Gunshot Wounds of the Knee Joint ..... V. R. Braitsev
On the Problem of the Treatment of Gunshot Wounds of the Knee Joint in a Front-Line Evacuation Hospital ..... F. F. David
Gunshot Wounds of the Knee Joint Complicated with Pyarthrosis ..... I. S. Vengerovsky
Gunshot Wounds of the Foot and Ankle Joint ..... B. V. Ognev

E. Kaplan, M.D., New York, N. Y.

THE PARATHYROID GLANDS AND PARATHORMONE. Alfred Pope and Joseph C. Aub. *The New England Journal of Medicine*, CCXXX, 698, 1944.

This is a comprehensive review of what is known about the parathyroid glands and parathormone, and it is accompanied by an extensive list of references. The article is too extensive for abstracting, but it should be studied and filed for further reference. The authors conclude that "the treatment of hypoparathyroidism has been rendered simple and effective and the surgical management of hyperparathyroidism placed on a sound basis".—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

A TOXIC FACTOR IN EXPERIMENTAL TRAUMATIC SHOCK. Joseph C. Aub. *The New England Journal of Medicine*, CCXXXI, 71, 1944.

The study of traumatic shock in World War I indicated that the cause of the syndrome was an unisolated toxin. Efforts to isolate this toxin were unsuccessful, and a reaction against the theory marked the period between the two wars. This was furthered by Blalock's and Phemister's convincing studies which showed the rôle of fluid loss in shock.

Because of the difference in appearance of both man and animals following bleeding and trauma, something other than plasma loss seems to be involved. In an effort to find this elusive factor, oedematous fluids from anoxic muscles were collected from experimental animals, and it was found that, in spite of rigid asepsis, such fluids were infected. Organisms of the gas-gangrene group were found in thirteen out of nineteen instances. The higher the number of the organisms, the more toxic or shock-producing were the effects, when the fluid was injected into animals. This toxic factor seemed to be something other than the organisms, because the supernatant fluid was equally toxic; while the injections of the organisms alone resulted only in fever. Considerable interest centers in the question as to whether clostridia are commonly present in muscles, or whether they are introduced at the time of the injury. In eighteen elective orthopaedic operations clostridia were not found, but it has been shown that more than 30 per cent. of war wounds are contaminated by clostridia. The characteristic slow onset of shock in the war wounded agrees with the length of time required for the growth of bacteria and the formation of their toxins.

These experiments show the great importance of plasma loss in shock, and they also show the importance of infection as a toxic factor. Fortunately, methods are now available for alleviating both plasma loss and infection.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

PAIN AND DISABILITY OF SHOULDER AND ARM DUE TO HERNIATION OF THE NUCLEUS PULPOSUS OF CERVICAL INTERVERTEBRAL DISKS. Jost J. Michelsen and William J. Mixter. *The New England Journal of Medicine*, CCXXXI, 279, 1944.

Cord compression was formerly considered a diagnostic criterion in herniation of the cervical discs; it now seems likely that this feature was overemphasized. Root symptoms may just as well occur here as in the lumbar area. Michelsen and Mixter found cord compression in six cases, while nerve-root involvement occurred in eight cases.

Eight cases which were operated upon, are reported in detail. It is indicated that pain and disability of the shoulder and arm were prominent symptoms. There were lesions at the fifth interspace in four cases, at the sixth in three, and at the seventh in one. The clinical data were brought together in a syndrome that comprised root pain and local sensory and motor disturbances, as well as positive roentgenographic and

cerebrospinal-fluid findings. The distribution of the sensory abnormalities was compared with standard dermatome charts. Emphasis is given to the importance of a systematic neurological examination in cases of pain and disability of the shoulder and arm. The removal of the disc fragments by laminectomy or subtotal hemilaminectomy gave good results. The addition of this new entity to the long list of disorders which give rise to arm and shoulder signs and symptoms ought to be a great help in the clarification of these perplexing problems.—*Paul P. Swett, M.D., Bloomfield, Connecticut.*

USE OF SKELETAL TRACTION IN THE HAND. Milton C. Cobey, Harvey C. Hansen, and Marion H. Morris. *Southern Medical Journal*, XXXVII, 309, 1944.

Skeletal traction is often more efficient than skin traction, and it is more comfortable. Considerably more pull can be obtained, and reduction is more accurate. A simple and convenient type of skeletal traction is the ordinary surgical towel clip. Routine aseptic surgical technique is followed, with draping of the parts. A small skin incision is made, and the traction device is placed in the proximal end of the incision to prevent skin tension. Sterile dressings are used about the clip, and are not to be disturbed until the fracture has united. Some type of fixation, corks or adhesive, may be employed to prevent to-and-fro excursions of the clip. Pull is exerted in the longitudinal axis of the bone. The clip is inserted under local or general anaesthesia, the fracture is reduced, and traction is applied. This device is useful in fracture or dislocation of the thumb and of the metacarpals. After the clip has been inserted and dressed, a plaster cast with a banjo splint for traction is applied. The clip is not used for fractures of the phalanges. The use of skeletal traction in fifty-nine cases is reported.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

CLINICAL ANALYSIS OF 1,000 CONSECUTIVE CASES OF LOW BACK PAIN. WITH PARTICULAR REFERENCE TO SCIATIC PAIN CAUSED BY EXTRUSION OF THE INTERVERTEBRAL DISC. Franklin Jelsma. *Southern Medical Journal*, XXXVII, 372, 1944.

It was found that 484 of 1,000 cases of low-back pain presented sufficient clinical findings to warrant a diagnosis of a probable herniated disc. Forty-seven other focal lesions were found,—such as, slight compression fracture of the bodies of the vertebrae, metastatic tumors, spina bifida occulta, spondylolisthesis, and sacralization of the fifth lumbar vertebra. In many cases, hypertrophic arthritic changes were found. Palliative measures were used in all cases so long as the patient improved. Operation was done in 150 cases. Only 26 per cent. of the patients did not give a history of injury. Ten patients had more than one disc injury. In 70 per cent., the lesions were located at the fifth lumbar vertebra, and in 25 per cent., at the fourth lumbar. In 6 per cent., no disc lesion was found. Results were good in 90 per cent., fair in 4.5 per cent., and unimproved in 1.5 per cent. (two cases). There were no deaths. The question of fusion was not discussed.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

LANTZOUNIS PERIOSTEO-CAPSULOPLASTY FOR CONGENITAL DORSAL SUBLUXATION OR CONGENITAL OVERLAP OF FIFTH TOE. Byron B. King. *Southern Medical Journal*, XXXVII, 614, 1944.

A simple operation is described to reduce and to maintain an overlapped or dorsally subluxated fifth toe. A dorsal incision is made over the metatarsophalangeal joint. The extensor digitorum longus tendon to the fifth toe is divided as far distally as possible. The periosteum and the capsule are stripped from the dorsal, medial, and lateral surfaces of the joint. A hole is bored just behind the head of the metatarsal; the extensor tendon is run through this, and is then sutured to itself under enough tension to raise the metatarsal head. The periosteum and capsule are folded under the joint and are fastened by a single figure-of-eight suture, which makes these tissues act as a bow-string ligament to hold the toe down in normal alignment. The wound is closed, and an adhesive plaster dressing is all that is needed to hold the toe in place.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

SURGICAL TREATMENT OF OSTEOMYELITIS OF THE EPIPHYSIS OF THE HUMERUS AFTER GUNSHOT FRACTURES. G. Kh. Sarkisov. *Sovetskaia Medicina*, VI, 17, 1944.

Gunshot injuries of the shoulder joint with destruction of the head of the humerus require a resection of the head before the possible development of osteomyelitis and pyarthrosis. Complete hemostasis must be obtained and the wound packed without complete closure. Only approximation of the wound edges is necessary. Closed plaster-of-Paris casts should be avoided. If there is a profuse discharge, the wound should be irrigated and sulfonamide therapy applied. Physiotherapy should be started only after complete closure of the wound. Resection of the shoulder joint may restore the shoulder to good use, and even permit the patient's return to limited combatant duty.—*E. Kaplan, M.D., New York, N. Y.*

THE EFFECT OF SEX HORMONES ON SKELETAL METASTASES FROM BREAST CANCER. J. H. Farrow. *Surgery*, XVI, 141, 1944.

Farrow has reviewed the findings upon which the use of sex hormones in the treatment of skeletal metastases has been based. Statistical evidence of the benefit of castration in the treatment of skeletal metastases has not been too encouraging. Approximately one-third of the patients in the premenopause period

were benefited by this procedure. Approximately one-half of the patients treated by means of testosterone showed evidence of clinical and roentgenographic improvement. On the other hand, the administration of large doses of the synthetic androgens tended to increase rather than inhibit the activity of skeletal metastases.

The author reported treatment of a case of carcinoma of the breast, in which there were widespread skeletal metastases, by means of bilateral orchidectomy. There was almost immediate relief of symptoms, and regression of both local and osseous metastases. Farrow hazards the opinion that this improvement will probably be temporary, although the results this far are encouraging.—*Edward L. Compere, M.D., Chicago, Illinois.*

LEONTIASIS OSSEA COMPLICATED BY MARJOLIN'S ULCER. OBSERVATION OF A CASE FOR TWELVE YEARS. R. E. Burger and E. P. Lehman. *Surgery*, XVI, 542, 1944.

Unusual pathological conditions should be studied and then reported for the benefit of the medical profession. This article by Burger and Lehman reports the case of a patient with leontiasis ossea, whom they have observed for twelve years.

The etiology of this rare condition is not known. The patient reported was twenty-eight years of age when he developed an extensive and painful swelling over the mandible, and a salivary fistula. Treatment consisted of surgical excision and x-ray therapy. Later the patient returned with a marked increase in the size of the tumor which was not sclerotic and involved the base of the skull and the upper cervical vertebrae. There was a large area of epidermoid carcinoma, with ulceration which was typical of Marjolin's ulcer.

—*Edward L. Compere, M.D., Chicago, Illinois.*

PANTOPAQUE. George M. Wyatt and Roy G. Spurling. *Surgery*, XVI, 561, 1944.

Wyatt and Spurling have reviewed the observations on six patients at the Walter Reed General Hospital when pantopaque was used as a contrast medium for myelography. In their opinion, although there is definitely some tissue reaction to pantopaque, the small amount of the material that is left permanently is of little consequence. Among the advantages of pantopaque is the fact that it is absorbed from the subarachnoid and the subdural spaces, and, since it is more fluid than the other contrast media, it fills smaller spaces and makes diagnostic myelography more accurate.—*Edward L. Compere, M.D., Chicago, Illinois.*

AN ANALYSIS OF THE MORE IMPORTANT ORTHOPEDIC INFORMATION. PRESENTED AT THE TWELVE REGIONAL FRACTURE ORTHOPEDIC CONFERENCES OF THE ARMY AIR FORCES. SPONSORED BY THE AIR SURGEON OCT. 18 TO NOV. 27, 1943. Alfred R. Shands, Jr. *Surgery*, XVI, 569, 1944.

Colonel Shands has again demonstrated his remarkably acute powers of observation and ability to coordinate information in this analysis of orthopaedic information which was presented at a series of regional fracture conferences of the Army Air Forces. In the twelve conferences, 196 papers were presented.

The material presented has been divided into anatomical groups. Shands has analyzed the methods and results of treatment of fractures and dislocations about the shoulder in part one; fractures and dislocations of the arm, forearm, and the elbow in part two; fractures and dislocations of the hand and the wrist in part three; fractures and dislocations of the hip, the thigh, and the knee in part four; fractures and dislocations of the leg and the ankle in part five; fractures and dislocations of the foot and the toes, part six; fractures and dislocations of the spine and the pelvis, part seven; compound fractures, part eight; conditions involving the back, part nine; conditions involving the knee, part ten; conditions involving the foot, part eleven.

After reviewing the material which was discussed, he has added a comment in which he expresses his own opinion and suggestions. This material is extremely interesting and instructive. It is already so condensed that it is impossible to attempt to abstract the paper itself. Every physician who is concerned with the problems of either traumatic surgery or the more everyday complaints of backache or painful feet, should avail himself of the opportunity of reading and studying the material which is presented in this excellent article.—*Edward L. Compere, M.D., Chicago, Illinois.*

FRACTURES OF THE CARPAL SCAPHOID IN THE CANADIAN ARMY. J. C. Dickison and J. G. Shannon. *Surgery, Gynecology and Obstetrics*, LXXIX, 225, 1944.

This is a study based on 257 cases of carpal scaphoid injuries collected from the Canadian Army overseas in a three-year period.

Union occurred in all cases of simple fresh waist fractures in twelve and a half weeks. Of six waist fractures with displacement of fragments, two united and four did not. In simple fresh proximal pole fractures diagnosed early, twenty weeks were required for union, the relative incidence of non-union was higher, and avascular necrosis was more prevalent.

No matter how astute the medical profession may become in the early diagnosis of fractured scaphoids, the late cases will always be present. So-called "sprained wrists" with roentgenograms negative for fracture should always be re-examined roentgenographically in two to three weeks. Among the late cases it was interesting to note that no fracture united in which diagnosis was made later than nine months after injury, and also that the fractures in which immobilization was continued for the longest periods without success

gave the poorest results. The late cases were treated by immobilization, by operation, or received no treatment, depending upon the judgment of the attending surgeons. How to obtain union consistently in these fractures, diagnosed so late, is still an unsolved problem. In severe disability, wrist fusion is still the last resort for the surgeon.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

PERILUNAR DISLOCATION OF THE CARPAL BONES AND DISLOCATION OF THE LUNATE BONE. W. Russell MacAusland. *Surgery, Gynecology and Obstetrics*, LXXIX, 256, 1944.

The purpose of this writer was threefold: (1) to emphasize again the importance of early diagnosis and treatment, (2) to describe in simple form the dislocations which concern the lunate bone, and (3) to present the observation and results in a series of twenty-four cases. There is general agreement that immediate manipulative reduction is the treatment of choice in fresh dislocations,—that is, in those less than two weeks old. Operative intervention is indicated (1) in fresh dislocations where there is a great deal of damage to the joint structures or to the median nerve, and (2) in cases of more than two weeks' standing. Operative replacement should not be attempted in a case of more than six weeks' standing.

A detailed end-result analysis is given in nineteen cases, and it was concluded that early manipulative treatment gave excellent results. Excision of the lunate, on the whole, resulted in a useful wrist. The majority of patients complained of weakness of the hand, and were unable to make a tight fist. Dislocations of the lunate of more than six weeks' standing are best treated by operative excision. The author states that the series fails to provide sufficient material on operative reductions to permit judging the relative value of operative replacement and excision of the bone.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

THE RÔLE OF THE NUCLEUS PULPOSUS IN THE PATHOGENESIS OF SO CALLED "RECOIL" INJURIES OF THE SPINAL CORD. Fritz Cramer and Francis J. McGowan. *Surgery, Gynecology and Obstetrics*, LXXIX, 516, 1944.

The authors have used the evidence available in one case of cord injury to present a new concept in the pathogenesis of lesions of the spinal cord, where no associated bone or ligamentous discontinuity is demonstrable. They believe that a violent protrusion of the intervertebral disc, by means of the hydraulic ramlike action of the nucleus pulposus when subjected to intense compressive force, causes the damage to the spinal cord. Autopsy findings in the one case showed the cord almost severed at a level directly opposite a sharp protrusion of the fifth cervical disc, while no abnormal vertebral protrusion, nor gross tearing of any posterior ligaments could be demonstrated.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

TOTAL AND PARTIAL PATELLECTOMY. Bernard N. E. Cohn. *Surgery, Gynecology and Obstetrics*, LXXIX, 526, 1944.

This was a well organized and controlled experimental study of total and partial patellectomy, performed on normal healthy rabbits. The results quite conclusively showed that total patellectomy, in either adult or immature rabbits, caused early degenerative changes of the tibiofemoral articulation, most marked in the adult rabbits. Partial patellectomy produced early degenerative changes of the femoral condyles in adult rabbits, but not in younger animals. In no case of total or partial patellectomy of adult or immature rabbits was there any clinical aberration of function. These facts led the author to conclude that total patellectomy should be undertaken in humans only when such procedure cannot be avoided.—*Carroll B. Larson, M.D., Boston, Massachusetts.*

HERNIATION OF MUSCLES OF THE LEGS. H. C. Goldberg and G. W. Comstock. *War Medicine*, V, 365, 1944.

This paper presents a brief review and discussion of the question of various kinds of hernias. The authors have classified hernias in general into two groups: those which are produced as a result of a congenital defect, and those which occur secondary to extensive pressure or atrophy, due to occupation or age. Muscle hernias may be constitutional or traumatic. Serious illness, local ulceration, or hypertrophy of muscles may be factors in the production of this entity. Most muscle hernias, however, result from sudden violence, and must be differentiated from lipoma, hematoma, tuberculosis, varices, and what the authors call "pseudohernia".

One diagnostic characteristic of muscle hernias is the fact that they can be reduced through the fascial defect and will disappear when the muscle contracts, while in the pseudohernia or rupture of the muscle, the bulge may become larger. Muscle hernias also tend to disappear on passive extension, a finding which is not present in thrombophlebitis and varicose veins.

The symptoms of muscle hernias include pain at the site of the lumps, associated with use of the muscles, and there may also be tenderness after exercise. The authors report one case and advise closure with a strip of fascia lata.—*Edward L. Compere, M.D., Chicago, Illinois.*